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DISSECTING ANEURYSM

A STUDY OF SIX RECENT CASES*

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IT IS our purpose in this paper to report six recent cases of dissecting aneurysm which were studied at the bedside, and to focus attention upon certain diagnostic criteria and problems which the study of these cases has emphasized. Only a few years ago, dissecting aneurysm was-seldom recognized clinically. The disease was usually misdiagnosed as ruptured peptic ulcer, cerebral thrombosis, arterial embolism, and, in the last decade, as coronary occlusion. In recent years, however, observations by Hamman and Apperley, Weiss, Tyson, and others have led to a better understanding of the clinical and pathologic manifestations of dissecting aneurysm, and in a number of cases the diagnosis has been made during life.

The chief signs and symptoms which have been described by most recent writers are severe substernal or epigastric pain, radiating to the back, neck, lumbar region, legs, and, rarely, to the arms; syncope; history of a previously existent hypertension; inequality or obliteration of peripheral pulses, with the sequelae of impaired circulation in the organ or region formerly supplied by the obliterated vessel; and an aortic diastolic murmur, often with the peripheral signs of aortic insufficiency. There may be slight fever, and leucocytosis, frequently as high as 20,000, is usually present. The electrocardiogram ordinarily shows no abnormality, but cases have been reported in which the tracings simulated those seen in coronary occlusion. Death usually occurs within a few hours or days. Occasionally, a patient lives for weeks or months or dies of some unrelated disease years after the dissecting aneurysm has been endothelialized and "healed."

^{*}From the Medical Service, Cincinnati General Hospital, and the Department of Internal Medicine, College of Medicine, University of Cincinnati. Received for publication Jan. 7, 1938.

Case 1.—C. G. H. 64331. The patient, a white man 56 years old, was admitted to the hospital Nov. 12, 1936, complaining of severe epigastric and precordial pain of nine hours' duration. During the previous afternoon, after a paroxysm of coughing, he was suddenly seized by a severe knifelike pain in the epigastrium that penetrated to the back, ascended into the chest, and radiated down both arms. He became so weak that he would have fallen had he not been supported. Although the pain soon abated, it kept him awake until two o'clock the next morning, when its intensity increased so much that he left his bed to search for a doctor. On his way down the street he collapsed, and was found by the police in an unconscious state. There was no history of syphilis, rheumatism, chorea, or of previous precordial pain. His blood pressure had never been taken previously. The cardiorespiratory history was negative, as was the remainder of the past history.

On admission the patient complained of "soreness" in the epigastrium, chest, and back. His temperature was 98.6° F., his pulse rate 64 per minute, his respiratory rate 22 per minute, and his blood pressure 105/60. He was moderately orthopneic. The radial pulses were of equal volume. The heart appeared to be slightly enlarged, the cardiac sounds were loud, and the heart was beating regularly and slowly. A soft systolic murmur, audible all over the precordium, was loudest at the aortic area; no diastolic murmur was heard. A few râles were heard at the base of the right lung. The abdomen was soft, but there was a point of tenderness over the xiphoid process; the liver was not palpable but seemed slightly enlarged to percussion. There was no peripheral edema.

The erythrocytes numbered 5,000,000 per cubic millimeter, and the leucocytes, 10,700. The hemoglobin content of the blood was 13.8 gm, per 100 c.c. The differential leucocyte count gave the following result: neutrophiles, 77 per cent; eosinophiles, 1 per cent; lymphocytes, 18 per cent; and monocytes, 4 per cent. Examination of the urine showed nothing except the presence of 4 to 6 leucocytes per high-power field. The Kahn test was negative on the blood serum and on the cerebrospinal fluid. Roentgenograms of the chest showed moderate enlargement of the heart; the aorta was very tortuous and elongated, and the descending portion appeared to be moderately dilated. Four serial electrocardiograms showed left axis deviation and a variation in the P-R interval of 0.2 to 0.24 sec. On admission, the T-wave in the Lead I was diphasic; three days later the S-T segment was elevated 0.7 mm. in the same lead, but this slight abnormality did not persist. The T-wave in Lead IV was diphasic on admission but later became inverted.

Five hours after admission, a moderately loud, early diastolic murmur was noted along the left border of the sternum. A diagnosis of dissecting aneurysm was made on the basis of the history and the appearance of this diastolic murmur. At this time the blood pressure was 110/45 in the left arm and 112/46 in the right arm. The radial, femoral, and dorsalis pedis pulses were equal in volume. A greatly increased systolic pulsation was noted in the left common carotid artery, and the patient complained of tenderness along this vessel. On the second day after admission, the diastolic murmur was considerably louder and was easily audible to the right of the sternum in the second intercostal space as well as along the left border of the sternum. The pulse was collapsing, and there was a pistol-shot sound in the femoral arteries. On November 19, eight days after admission, a mid-diastolic murmur was first heard at the apex; this was thought to be an Austin Flint murmur. For the first two weeks morphine was required periodically to give relief from pain, but after that the patient gradually improved and at the end of a month was able to be up in a wheel chair. By this time the tenderness and increased pulsation in the left carotid artery had disappeared. At the end of six weeks he was walking about. The blood pressure was measured on numerous occasions and was found to

average 120/45, with a maximum of 135/65. On December 2 he suffered for the first time from attacks of paroxysmal dyspnea. On December 29 he developed clinical evidence of pulmonary infarction and expectorated bloody sputum. Thereafter he grew worse steadily. Pain beneath the sternum and in the back, combined with moderately severe dyspnea, made his life miserable. He died Jan. 24, 1937, of bronchopneumonia. The murmurs over the heart remained unchanged until the last.

The post-mortem diagnoses* were dissecting aneurysm of the aorta; atherosclerosis of the aorta; cardiac hypertrophy and dilatation with myocardial degeneration; chronic passive congestion of the spleen and liver; chronic cholecystitis and cholelithiasis; and lobular pneumonia. The pericardial sac contained 75 c.c. of serosanguineous fluid. The heart, which was hypertrophied and dilated, weighed 600 gm. There was no organic disease of the valves. The coronary arteries appeared normal. The aorta was markedly dilated throughout. Numerous atherosclerotic plaques, some of which were filled with calcareous deposits, were noted in the intima. Between the sixth and the ninth thoracic vertebrae the aorta was dissected by a large amount of partially clotted blood, splitting the media throughout threequarters of the circumference of the vessel, namely, the posterior, the left lateral, and the anterior aspects. The dissection apparently had begun in this region, and had extended upward to a point just distal to the sinuses of Valsalva, and downward to the bifurcation of the abdominal aorta. No tear of any kind was found in the intima of the aorta. The intercostal and lumbar arteries were torn across as they traversed the sac. The dissection also extended about 1.5 cm. up the lateral half of the left common carotid artery. Sections through this area showed that the outer portion of the media and the inner part of the adventitia were involved. Most of the blood had been replaced by fibrous tissue, within which were seen many small nerve trunks. Sections through the vessel showed no evidence of its having been occluded. None of the other vessels arising from the aortic arch was involved. The lungs were the seat of bronchopneumonia, chronic passive congestion, and edema. The liver and spleen showed changes characteristic of passive congestion.

Comment.—Although the onset of the disease in this patient was quite typical, the case presents several interesting and unusual features. One of the less common signs of dissecting aneurysm is an aortic diastolic murmur. Resnick and Keefer⁵ called attention to this phenomenon in 1925, and in 1933 Hamman and Apperley¹ diagnosed the disease by this means. So far as we have been able to ascertain from the literature, this is the first reported case in which the diastolic murmur has been observed to develop after the onset of symptoms. Inasmuch as some authors,5,13 give credence to the theory that these murmurs, as well as the peripheral manifestations of aortic insufficiency, may be caused by the backflow of blood into the aneurysmal sac during diastole, it is significant that in this case there was neither a tear in the intima of the aorta nor any sign of communication of the lumen of the aorta with the aneurysm. Wood, Pendergrass, and Ostrum¹⁰ and Hamman and Apperley have suggested that the explanation lies in a relative insufficiency of the aortic valve caused by dilatation of the ring, following upon dissection of the aortic coat down to the valve cusp. In the present case there is nothing inconsistent with this hypothesis.

^{*}The post-mortem examinations in all of the cases reported herein were performed in the Institute of Pathology of the College of Medicine of the University of Cincinnati,

Though decrease in the volume of one or more peripheral pulses is frequently noted in dissecting aneurysm, this patient presented a striking increase in the pulse volume of the left common carotid artery with tenderness along the course of the vessel. Inasmuch as this vessel was the only one arising at the aortic arch which was involved in the dissection, this sign takes on added importance. Microscopic examination showed that many nerve fibers were involved in the dissection, and therefore it seems likely that spontaneous periarterial sympathectomy occurred, with a resulting dilatation of the vessel similar to that which follows surgical sympathectomy. The pain and hyperesthesia which accompanied the dilatation and disappeared when the arterial tone was regained likewise may have been brought about by involvement of the arterial nerve plexus. It is of interest that Weiss² has suggested that similar involvement of the depressor nerve endings in the aortic arch may be responsible for the syncope of dissecting aneurysm.

CASE 2.—C. G. H. 68188. The patient was a colored male bricklayer, 51 years of age, who was admitted to the hospital on Feb. 7, 1937, complaining of pain in the chest and abdomen of twenty hours' duration. On the day before admission, while crossing the street, he was suddenly stricken with a severe viselike pain in the lower cervical region which radiated to the lower sternal region, into both arms, and down the abdomen. Although he was very weak, he was able to make his way home, where he crawled into bed and soon lost consciousness. He recovered consciousness, only to be harassed by pain, nausea, and vomiting.

Six weeks before the onset of his present illness he had come to the dispensary complaining of lumbago. At this time the blood pressure was 200/130.

On admission to the hospital the patient appeared to be in a state of circulatory collapse. His temperature was 99.2° F., his pulse rate 104 per minute, and his respiratory rate 24 per minute; his blood pressure could not be measured. He preferred to lie on the right side. The fundi showed arteriosclerotic changes. The heart was enlarged; the sounds were very distant; there were no murmurs or friction rubs. The radial pulses were very feeble, but equal in volume, and the dorsalis pedis pulses could not be felt. The lungs were not demonstrably abnormal. Except for slight epigastric tenderness, the abdomen was negative.

The erythrocytes numbered 4,730,000 per cubic millimeter, the leucocytes 17,000. The hemoglobin content of the blood was 14.4 gm. per 100 c.c. The differential leucocyte count revealed 74 per cent neutrophiles, 20 per cent lymphocytes, and 6 per cent monocytes. The urine contained albumin (2-plus), 10 to 15 leucocytes per high-power field, and a few hyaline casts. The Kahn test on the blood serum was negative. The blood urea nitrogen was 50 mg. per cent. No roentgenograms were made. Electrocardiograms were taken on each of the three days the patient was on the ward (Fig. 1). Chief interest centered upon the T-wave and S-T segments in Leads II and III. In Lead II the T-wave was upright at the time of admission, and the S-T junction was isoelectric. On the second day the S-T junction was elevated 1 mm., and on the third day, 2 mm. The T-wave in Lead II became inverted on the third day. In Lead III the T-wave was upright and the S-T junction isoelectric at the time of admission. On the second day the S-T complex was of the "coronary" type, with suggestive "cove-plane" appearance, and the T-wave was inverted. On the third day, the T-wave was still deeper in Lead III. There was a persistent Q-wave in Lead III that measured approximately 33 per cent of the highest R-wave.

Because of the character of the pain, the history of hypertension, and the syncope, an initial diagnosis of dissecting aneurysm was made by two observers; others favored a diagnosis of myocardial infarction. Following supportive treatment the patient improved considerably, so that by the second day after admission his blood pressure had risen to 150/120. No cardiac murmurs or friction rubs were heard. There were no signs of fluid in the pericardium. On the third day after admission, the patient sat up in bed, beckoned to an orderly across the ward, and fell over dead.

The post-mortem diagnoses were dissecting aneurysm of the ascending aorta with rupture into the pericardium; slight aortic and coronary atherosclerosis; and chronic passive congestion of the liver and lungs. The pericardial sac was distended by 950 c.c. of blood. The right pleural cavity contained 300 c.c. of blood-tinged fluid, and the left 175 c.c. The source of the blood in the pericardial sac was found to be a rent 7 mm. in length in the outer coats of the right lateral aspect of the ascending aorta, 5 cm. above the base of the left ventricle and below the point of reflection of the pericardium. The rent communicated with a large space within the

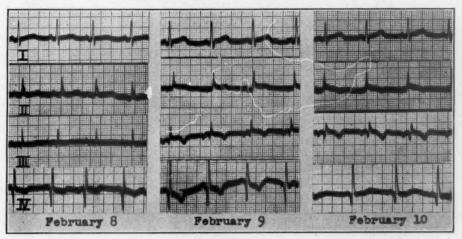


Fig. 1.—Serial electrocardiograms in Case 2.

wall of the ascending aorta. This space extended upward to within 1.5 cm, of the mouth of the innominate artery and downward behind the aortic valve. It was filled with clots of blood that separated the outer from the inner layer of the media of the vessel. Blood had invaded the subepicardial tissues and was present in the subepicardial layer of fat in the region of the aortic ring. Blood had also invaded the myocardium in this region, and completely surrounded the right coronary artery at a point about 1 cm. below its origin. The intima of the aorta was the seat of mild atherosclerosis, but there was no tear through this coat and careful search failed to reveal any connection between the aorta and the aneurysmal cavity. There was no evidence of syphilis. The heart valves were normal. The intima of the coronary arteries showed changes indicative of slight atherosclerosis. The heart was normal except for the portion invaded by blood. There was no gross or microscopic evidence of infarction. There was chronic passive congestion of the liver and lungs.

Comment.—The electrocardiograms in this case deserve comment because they simulated those of acute coronary occlusion (Fig. 1). The

progressive elevation of the S-T segment and inversion of the T-wave in Leads II and III are ordinarily considered characteristic of myocardial infarction involving the posterior and basal portions of the heart. These areas are supplied by the right coronary artery, which was the vessel involved by the dissection in this case. The progressive. increase in depth of the Q-wave in Lead III is also evidence of a changing myocardial process. Even more striking "coronary" changes were reported by Elliot and Evans¹⁴ in a case of ruptured abdominal aneurysm, and by Osgood, Gourley, and Baker¹¹ in a case of dissecting aneurysm in which no myocardial infarct was found. In Elliot and Evans's case, though no infarct was found, the coronary arteries were definitely narrowed. Their explanation was that in the presence of already narrowed coronary arteries the diminished blood flow associated with vasomotor collapse may have created sufficient anoxemia of the myocardium to bring about the changes in the electrocardiogram. Glendy, Castleman, and White¹³ describe a case with "slight T-wave changes in Leads II and III, suggestive of cardiac infarction of the posterior or diaphragmatic type." They found that the aortic dissection involved the opening of the right coronary orifice. McGeachy and Paullin⁷ reported a case of dissecting aneurysm with hemopericardium in which there were progressive T-wave changes, namely, inversion of a previously upright T-wave in Leads I and II.

In our patient, gross and microscopic studies failed to reveal evidence of coronary disease or of myocardial infarction. However, in the myocardium there was an ecchymosis which completely surrounded the right coronary artery and extended 1.5 cm. down the arterial trunk on all sides. It has been shown experimentally in dogs that electrocardiographic evidence of acute myocardial ischemia, characterized by distortion of the T-wave and elevation or depression of the S-T segment, frequently begins to manifest itself in Leads I, II, III, or IV after the cross section of a major coronary artery has been reduced by approximately 30 to 50 per cent. Moreover, such hearts may show no evidence of myocardial infarction after periods of partial occlusion lasting one to two months. It seems reasonable to conclude, therefore, that in this case partial occlusion of the right coronary artery was probably effected during life by the blood which, at autopsy, was found to surround the vessel.

It may be argued that the electrocardiographic changes were the result of the hemopericardium. It is difficult to explain, on this basis, changes in the electrocardiogram that made their appearance one to two days previous to the patient's death, since the size of the tear in the aorta would suggest that leakage into the pericardium took place rapidly, causing a quickly fatal cardiac tamponade. That such was the case is borne out by the clinical course, for the patient presented no evidence of pericardial effusion up to the time of his sudden death.

At autopsy there was no connection between the ecchymosis about the coronary vessel and the tear responsible for the hemopericardium. Moreover, the elevation of the S-T segment was restricted mainly to Leads II and III, indicating a localized process, whereas, according to Schwab and Herrmann, 16 the S-T segment elevation seen in pericardial effusion ordinarily takes place in all three conventional leads and is the result of generalized myocardial ischemia. It is unlikely, therefore, that the hemopericardium was responsible for the electrocardiographic changes.

Case 3.—C. G. H. 67451. The patient was a 55-year-old motorman, who was admitted to the neurologic service January 22, 1937, complaining of a "stroke." He had been standing about the carbarn when suddenly, without any warning, he fainted and fell to the ground. He was brought to the hospital in a stuporous condition. Later he stated that a moment before fainting he had a feeling that someone was drawing a rope tightly around his chest. However, he did not complain of pain at any time. Eight years previously he had been examined by a physician who told him his blood pressure was 265. There was no history of angina pectoris or of other cardiorespiratory symptoms.

On examination the temperature was 98° F., the pulse rate 52 per minute, and the respiratory rate 16 per minute. The blood pressure in the right arm was 68/60 and in the left arm 115/70. The patient was semistuporous but could answer questions slowly. The heart did not appear enlarged to percussion, but the retromanubrial dullness was increased. The heart sounds were very distant, and there was a systolic murmur at the base. The pulse in the right radial artery was imperceptible, but that in the left was easily felt. The lungs and abdomen were negative. The patient presented signs of left-sided hemiparesis. A diagnosis of cerebral hemorrhage was made, and the possibility of a syphilitic aortic aneurysm was entertained.

The erythrocytes numbered 3,100,000 per cubic millimeter, and the leucocytes 19,000. The hemoglobin content of the blood was 13 gm, per 100 c.c. The differential leucocyte count showed 92 per cent neutrophiles, 4 per cent lymphocytes, and 4 per cent monocytes. Examination of the urine revealed a moderate amount of albumin (1-plus), a few leucocytes, and numerous hyaline casts. The Kahn test on the blood serum was negative. The cerebrospinal fluid pressure was 250 mm, of water; the fluid was pink, contained 6,000 erythrocytes per cubic millimeter, and gave a negative Wassermann reaction. No roentgenograms or electrocardiograms were made.

There was no change in the patient's condition until thirty-three hours after admission, when he suddenly waved his arms about and fell over dead.

The post-mortem diagnoses were dissecting aneurysm of the aorta with rupture into the pericardial sac; marked cerebral atherosclerosis with recent infarction of the right lenticular nucleus; cardiac dilatation and hypertrophy; chronic passive congestion of the liver, lungs, and kidneys; and aortic and coronary atherosclerosis. The pericardial sac was distended by 250 c.c. of blood, much of which had clotted. The heart weighed 700 gm. Both sides of the heart were dilated, and the left ventricle was hypertrophied as well. The heart valves appeared normal. The coronary arteries were the seat of moderate atherosclerotic changes. Arteriosclerotic plaques were noted along the intima of the aorta. A transverse tear in the intima of the aorta, 2.5 cm. long and 2 mm. wide, was noted about 4 cm. above the aortic valve. This tear communicated with a cavity between the media and adventitia which extended from the level of the attachment of the aortic valve along the entire length of the aorta to the origin of the common iliac vessels. The lumen of the cavity was partially filled with blood clots, some relatively old and others

of more recent origin. Investigation of the great vessels arising from the arch of the aorta was not carried out at autopsy. There was passive congestion of the lungs, liver, and spleen. The liver was infiltrated with fat. There was a fresh area of softening in the right lenticular nucleus, surrounded by an area of edema partly involving the internal capsule.

Comment.—This patient is one of two (Cases 3 and 6) in this series in whom the presenting clinical manifestation was that of hemiplegia, a not unusual finding in dissecting aneurysm. Of significance, also, is the fact that the patient did not complain of pain. The most striking feature of the onset of the illness was the occurrence of syncope, preceded by a feeling of tightness in the chest.

Case 4.—C. G. H. 67006. This patient was an unemployed white man, 70 years of age, who was brought to the hospital Jan. 11, 1937, in a semicomatose condition, unable to give a history. After his death, the following facts were obtained from his landlady. The patient had been in fair health until several weeks before he was admitted to the hospital. For about four weeks before admission he had suffered from epigastric pain of unknown nature, and anorexia, but his ordinary activities had not been curtailed. Two days before admission, he was forced to go to bed, apparently because of weakness. During this time he did not complain of pain. On the day of admission he fainted after arising from his bed. When his landlady found him he was able to recognize her, was very weak, and unable to talk. The only fact obtainable in the past history was that the patient had been discharged from a tuberculosis sanatorium twenty-two years previously.

On admission the patient appeared dehydrated. The skin was pale, cyanotic, and cold. The temperature was 95° F., the pulse rate 84 per minute, and the respiratory rate 26 per minute. The blood pressure was 96/70. Ophthalmoscopic examination showed blurred disk margins, compression of veins by arteries, flame-shaped hemorrhages, and old exudate. Dullness and numerous râles were detected over the upper anterior region of the left chest. The location of the heart borders could not be determined by percussion, but the heart sounds were of normal intensity and quality. A rough systolic murmur was heard over most of the precordium. The radial and dorsalis pedis pulses were readily palpable and equal in volume. The abdomen was negative.

The erythrocytes numbered 4,200,000 per cubic millimeter, the leucocytes 20,750. The hemoglobin content of the blood was 10 gm. per 100 c.c. The differential leucocyte count revealed 85 per cent neutrophiles, 1 per cent eosinophiles, 10 per cent lymphocytes and 4 per cent monocytes. The urine contained a trace of albumin and a great deal of sugar (4-plus). Tests for acetone and diacetic acid were negative. The urinary sediment contained 50 leucocytes per high-power field, 2 erythrocytes per high-power field, and an occasional hyaline cast. The Kahn reaction on the blood serum was negative. The cerebrospinal fluid pressure was 180 mm. of water. The fluid was clear and contained only 4 lymphocytes per cubic millimeter, but the Pandy reaction was positive (2-plus). The blood sugar was 363 mg. per cent, the carbon dioxide combining power, 33 volumes per cent; and the blood urea nitrogen, 15 mg. per cent. Two electrocardiograms showed frequent auricular premature beats. The P-R interval varied from 0.16 to 0.24 sec. The T-wave was isoelectric in Lead I, and a small Q-wave was present in Lead III. No roentgenograms were obtained.

The patient was moribund on admission and died thirty-five hours later without regaining consciousness. The clinical diagnoses were coronary occlusion, diabetes mellitus, and fibroid pulmonary tuberculosis.

The post-mortem diagnoses were dissecting aneurysm of the aorta with rupture into the left pleural cavity; arrested apical fibroid tuberculosis; chronic passive congestion and edema of the lungs; severe generalized atherosclerosis; myocardial fibrosis and degeneration; and chronic passive congestion of the liver and spleen. The pericardial sac contained 50 c.c. of straw-colored fluid. The heart weighed 395 gm. The myocardium was diffusely fibrosed. The valves were normal. The coronary arteries were tortuous, sclerotic, and in some places calcified; their lumina were narrowed, but patent throughout. The aorta was moderately dilated and was the seat of extensive atherosclerosis. A tear through the intima which communicated with a space between the layers of the media was found in the descending portion of the aorta, 4 cm. below the arch. This cavity extended upward to a level about 3 cm. above the intimal tear and downward to the bifurcation of the abdominal aorta. Another tear, through the outer layer of the media and adventitia, connected the aneurysmal space with the left pleural cavity, which contained partly organized blood and about 500 c.c. of serosanguineous fluid. The lungs showed edema and chronic passive congestion. There were old fibrous tuberculous lesions at both lung apices. There was chronic passive congestion of the liver and spleen. The pancreas was normal.

Comment.—Because of the meager history in this case, the nature of the epigastric pain from which the patient suffered could not be ascertained. Apparently the pain was not severe enough to cause the patient to limit his activities or to seek medical advice. According to those in closest contact with the patient during the final illness, the outstanding complaint was weakness and, finally, syncope.

CASE 5.—C. G. H. 75763. The patient was a white male clerk 65 years of age, who was admitted to the hospital June 11, 1937, complaining of having "passed out." He had just finished his noon meal that day when he became aware of a feeling of oppression beneath the lower sternum and numbness in the left arm down to and including the little and ring fingers. He had no pain, dyspnea, or cough. He soon became so weak that he fell to the floor and had to be brought to the hospital. The past history was irrelevant.

Physical examination revealed a well-developed thin man who was conscious but obviously in a state of circulatory collapse. The temperature was 95° F., the heart rate 90 per minute, and the respiratory rate 20 per minute. It was impossible to measure the blood pressure in either arm. The skin was cold, pale, and moist. The lips and fingertips were cyanotic. The pupils were equal, regular, and reacted to light and in accommodation. Examination of the fundi revealed arteriosclerotic changes in the vessels, but no retinal hemorrhages or exudate. The trachea was in the midline; there was no tracheal tug. The lungs were negative. Percussion showed that the heart was slightly enlarged to the left, and the apex beat was in the fifth interspace 10 cm. to the left of the midline. The heart sounds were very distant, and the heart was grossly irregular. No murmurs or friction rubs were heard. The peripheral pulses could not be felt. The abdomen was negative.

The erythrocytes numbered 3,700,000 per cubic millimeter, and the leucocytes 21,000. The hemoglobin content of the blood was 12 gm. per 100 c.c. The differential leucocyte count showed 80 per cent neutrophiles, 1 per cent eosinophiles, 18 per cent lymphocytes, and 1 per cent monocytes. The Kahn reaction on the blood serum was negative. The electrocardiogram showed nothing but numerous auricular and ventricular premature beats.

Following the intravenous administration of 700 c.c. of a 5 per cent glucose solution, the blood pressure was obtained at 50/30, and the patient seemed somewhat

improved. However, while talking to a nurse, he suddenly began to moan and toss about and within a few minutes was dead. Death occurred thirteen hours after the onset of symptoms. The clinical diagnosis was coronary thrombosis.

The post-mortem diagnoses were dissecting aneurysm of the aorta; moderately severe aortic and coronary atherosclerosis; cardiac hypertrophy; myocardial fibrosis and degeneration; and chronic passive congestion of the lungs. The autopsy was limited to the thorax. The pericardial sac contained 125 c.c. of blood and numerous blood clots. The heart was enlarged and, with the attached aorta, weighed 860 gm. The left ventricle was hypertrophied. The endocardium and valves were normal. The lumen of the anterior descending branch of the left coronary artery was narrowed by intimal atherosclerosis. The other coronary vessels showed slight sclerosis, but their lumina were not narrowed. In the intima of the aorta were numerous elevated yellow plaques, many of which were calcified. About 4 cm. above the level of the aortic valve was a linear, irregular, intimal tear, through which the lumen of the aorta communicated with a cavity which had formed between the outer layers of the media. This cavity, which was partially filled with fresh and organizing blood clots, extended from the level of the aortic valve to the bifurcation of the aorta. Near its cardiac end the dissecting aneurysm communicated directly with the pericardial sac. The blood had dissected upward along the innominate artery into the right subclavian and common carotid vessels, and also had progressed for a distance of 1.5 cm. along the posterior half of the left common carotid and left subclavian arteries. The dissection involved most of the intercostal vessels, as well as the abdominal branches of the aorta. The lungs were congested and edematous.

Case 6.—C. G. H. 77601. This patient was a white housewife, 59 years of age, who was admitted to the hospital July 24, 1937, in a stuporous condition. According to her daughter, the patient had been in fairly good health until six days before admission, when during an automobile ride she suddenly felt faint and had to be taken home. Following this episode she did not seem ill except for slight difficulty in talking, and continued in good health for two days. At the end of this time generalized weakness forced her to go to bed; she gradually became drowsy but did not lose consciousness. She was able to move all her extremities, and at no time complained of pain. Since the age of seventeen years, her general health had been good except for frequent headaches. Six years previously, she had been told by a physician that her blood pressure was 300. At that time her ankles had been swollen, but aside from this fact there was no history of cardiorespiratory symptoms.

Physical examination revealed an elderly woman lying quietly in bed, stuporous, but not unconscious. The temperature was 99.6° F., the pulse rate 88 per minute, and the respiratory rate 20 per minute. The blood pressure was 220/110 in each arm. The retinal arteries were narrowed, and there were a few old retinal hemorrhages. The lungs were not demonstrably abnormal. The heart was enlarged, and a systolic murmur was heard at the apex. The abdomen was normal. Neurologic examination was unsatisfactory because of poor cooperation. There was evidence of motor aphasia, right-sided facial paresis, and weakness of the right arm and right leg. The abdominal reflexes were not obtained, but the tendon reflexes were normal; no abnormal plantar signs were elicited. A diagnosis of hypertension and thrombosis of the left lenticulostriate artery was made.

The erythrocytes numbered 3,570,000 per cubic millimeter, and the leucocytes 11,000. The hemoglobin content of the blood was 12.5 gm, per 100 c.c. The differential leucocyte count was normal. The urine contained albumin (3-plus) and a few hyaline casts. The Kahn reaction on the blood serum was negative. The cerebrospinal fluid was normal. No roentgenograms were made. The course of the patient's illness was uneventful for fifty-six hours, when she died suddenly.

The post-mortem diagnoses were dissecting aneurysm of the aorta, with hemopericardium; extensive generalized atherosclerosis; arterio- and arteriolonephrosclerosis; coronary sclerosis; myocardial fibrosis; cardiac hypertrophy, pulmonary congestion and edema; chronic cholecystitis and cholelithiasis; and chronic passive congestion of the liver. The pericardial sac was distended and contained 500 c.c. of blood. The heart was not weighed separately, but with the pericardium and thoracic aorta weighed 600 gm. The cardiac muscle was hypertrophied and fibrotic. The heart valves were normal. The coronary arteries were rigid and tortuous, but the lumina were patent. The aorta was dilated, and the intima lined with many atheromatous and calcified plaques. At a point 2.5 cm. above the aortic valve, on the posterior wall of the aorta, was a transverse intimal tear which communicated with a cavity between the medial and adventitial coats. On the exterior surface of the aorta, but on the anterior aspect, was another perforation, 2 mm. in diameter, which communicated with the pericardial cavity. The aneurysmal cavity surrounded the aorta completely from the beginning of the ascending aorta to the midportion of the thoracic aorta; but from this point down to, and including, the first portion of the celiac arteries, only one-half to three-quarters of the circumference of the vessel wall was involved. All the vessels arising from the arch of the aorta were extensively involved, and both common carotid arteries were dissected as high as their bifurcations. Throughout the course of both common carotid arteries the clot bulged into the lumina, causing marked reduction of their caliber. There was chronic passive congestion of the lungs and liver. The kidneys were small, contracted, and weighed 150 gm. The surfaces presented coarse and fine granulations, and the cortices were grossly distorted. There were no gross abnormalities of the gastrointestinal tract. The cerebral arteries were the seat of advanced atherosclerosis, leading to marked narrowing of the lumina. Except for a few old tiny areas of softening, the brain was not remarkable; there was no gross infarction.

DISCUSSION

In addition to the unusual manifestations presented by the first two cases, consideration of the character of the disease in the entire group of six cases which we have reported brings out several unusual features which deserve comment. The common conception of the onset of dissecting aneurysm is that of a sudden dramatic catastrophe which is ushered in by unbearable pain. In view of this conception, it is significant that only two of our patients suffered from severe pain and that three were apparently free from pain throughout their illness. Wood, Pendergrass and Ostrum¹⁰ have previously called attention to the absence of pain in dissecting aneurysm. Most observers also state that the arterial pressure is typically high in dissecting aneurysm and that the presence of hypertension is an important sign in the differential diagnosis between this condition and myocardial infarction. In our cases, five of the six patients either had normal blood pressure or were in a state of peripheral circulatory collapse at the time of admission.

The outstanding symptom in all six cases was syncope or weakness. Four of the six patients herein reported fainted either at the onset of their illness or shortly thereafter, and the remaining two suffered from dizziness and weakness but did not actually lose consciousness. Though

we have no statistical information concerning the occurrence of syncope in coronary occlusion, it is certainly not a common initial symptom. On the other hand, fainting is quite common in dissecting aneurysm, 2, 3, 10 and is frequently the presenting symptom. In view of the difficulties of differentiating between coronary occlusion and dissecting aneurysm, this symptom, either in the presence or absence of pain, takes on considerable importance.

It is of interest that six cases of dissecting aneurysm were encountered within the short space of seven months, in view of the fact that in the preceding nine years only ten cases had come to necropsy at this hospital.17

SUMMARY

Six cases of dissecting aneurysm of the aorta, autopsied between January and July, 1937, are reported. In two cases the correct diagnosis was made during life.

One patient presented a conspicuous increase in the pulse volume of the left common carotid artery. Dissection along this vessel causing interference with the periarterial sympathetic plexus is proposed as the explanation of this sign.

One patient presented electrocardiographic changes characteristic of coronary occlusion, which apparently resulted from extravasation of blood about the right coronary artery.

Four patients lost consciousness at the onset, and all complained of dizziness or weakness. The importance of syncope in the differential diagnosis between dissecting aneurysm and coronary thrombosis is discussed.

Pain was not a prominent symptom in four of the six cases.

An elevated blood pressure at the time of admission was observed in only one case.

Intimal tears were observed in four cases.

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THE VECTORCARDIOGRAM*

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INTRODUCTION

Y/ALLER, who was the first to obtain graphic records of the electric currents produced by the human heart, had a clear conception of the relation between the direction of the cardiac electromotive force and the relative potential of the various extremities. One of his early papers,1 published in 1889, contains a diagram which shows the distribution of the isopotential surfaces within the trunk when the electrical axis of the heart has a base-apex direction. In 1913 Einthoven, Fahr, and de Waart2 devised a method of computing the "manifest" magnitude and the direction of the resultant electromotive force produced by the heart at a given instant during the cardiac cycle. They made extensive use of this method in studying the influence of the respiratory changes in the position of the heart upon the form of the ventricular complex. In the same article they published an enlarged reconstruction of a normal electrocardiogram in which the QRS complexes of the three leads were arranged one above the other in their proper time relations so that simultaneous points fell on the same ordinate. This reconstruction enabled them to measure accurately the voltage recorded in each lead at ten successive instants equally spaced throughout the QRS interval, and thus to compute the corresponding value of E, the "manifest" magnitude of the cardiac electromotive force, and of a, the angle which defines its direction with respect to the horizontal. This method of analyzing the electrocardiogram was later employed by Williams,3 and by Lewis,4 who made important use of it in his studies of bundle branch block, of ventricular hypertrophy, and of auricular flutter.5 Lewis laid great emphasis upon the rotation of the electrical axis because he believed that the changes in the direction of this axis gave direct evidence of similar and coincident changes in the direction in which the excitatory process as a whole was spreading over the cardiac muscle.

Since the resultant electromotive force produced by the heart at a given instant has both magnitude and direction, it may be represented by a vector drawn from the center of Einthoven's triangle as origin. When the excitatory process is advancing or retreating the size and direction of this vector vary from instant to instant so that its terminus describes a continuous curve. In mathematical language, this curve is a vector function of the time. In 1920 Mann, tutilizing data

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published by Einthoven and his associates as well as material of his own, constructed a number of curves of this kind and called them monocardiograms. Granting the priority of this name, we prefer to call them vectorcardiograms in order to emphasize the true nature of the difference, in a mathematical sense, between them and ordinary electrocardiographic curves, which are scalar functions of the time. In 1931 Mann⁷ published a second article on this subject in which he stated that he had constructed an apparatus which made it possible to record the monocardiogram directly. We understand that this apparatus was demonstrated on one or more occasions, but it has not been described in the literature and no curves taken with it have been published.

A few years ago we became interested in the possibility of using the cathode-ray oscillograph for this purpose. Having found this feasible, we have constructed the necessary apparatus and have taken a considerable number of entirely satisfactory curves. The methods employed were described and sample curves of various types were shown at a meeting of the American Society for Clinical Investigation, in May, 1937. At that time we were not aware of any work along this line other than the studies already mentioned. In August, 1937, however, Hollmann and Hollmann⁹ described a somewhat different method of using the cathode-ray oscillograph to record the vectorcardiogram and called attention to Schellong's work, which was presented at a medical meeting in Germany in April, 1936. Thus, as often happens, technical improvements, in this instance in the design of the cathode-ray tube, led to the independent development of similar methods in several places at about the same time.

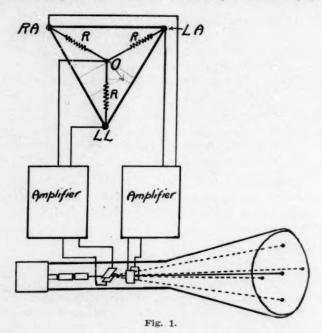
METHODS

In principle the method we have employed is exceedingly simple. The inner surface of the larger end of the cathode-ray tube is coated with fluorescent material. Where the beam of electrons generated by the tube strikes this screen a brilliant luminous spot is produced. By varying the voltages on the different electrodes, the beam of electrons may be focused, the velocity of the electrons constituting the beam may be varied, and the beam current may be controlled. The tube is provided with two sets of deflecting plates; a difference in potential between the plates of the first set shifts the beam, and hence the luminous spot, in the vertical direction, and a difference in potential between the plates of the second set shifts the beam in the horizontal direction. Within wide limits the displacement of the beam in either direction is strictly proportional to the voltage applied to the corresponding set of plates. The displacement takes place practically instantaneously when the voltage is applied, and no overshooting occurs. The sensitivity of the cathoderay tubes we have used is such that about twenty-five volts are required to move the luminous spot through a distance of 1 cm. In order, therefore, to obtain satisfactory vectorcardiograms the voltages obtained from the electrodes on the extremities must be amplified at least 25,000 times, and much greater amplification is desirable.

The connections between the body and the deflecting plates of the cathode-ray tube are arranged as indicated in Fig. 1. The right-arm and left-arm electrodes are connected through a suitable amplifier to the deflecting plates which shift the

spot in the horizontal direction, or along the x axis. The polarity is so arranged that relative negativity of the right-arm electrode displaces the spot to the right, and relative positivity of this electrode displaces it to the left. The gain-control of the amplifier is adjusted until the spot moves 1, 2, or 3 cm. when one millivolt is introduced into the input circuit. The spot then moves back and forth along the x axis in step with the difference in potential between the two arms, and, if its movements are photographed on a film moving at a uniform speed, standard Lead I is faithfully recorded.

Einthoven and his associates showed that if the magnitude of the cardiac electromotive force is represented by E and the angle which defines the direction of this force with respect to the x axis by a, the deflection in Lead I is equal to E cos a. This is the horizontal component of the cardiac vector, and it is obtained as described in the preceding paragraph. In order to obtain the vertical component, we make use of a simple network. The three extremity electrodes employed in taking



the standard limb leads are connected through equal resistances of 5,000 or more ohms to a central terminal. In previous communications 11, 12 it has been shown that, when this is done, the difference in potential between the central terminal and the left-leg electrode must always be equal to one-third the sum of the potential differences recorded by Leads II and III. It has also been shown that one-third of the sum of these potential differences is equal to $E\sin\alpha$, the vertical component of the cardiac vector, divided by $\sqrt{3}$. In order to place this component upon the F axis of the cathode-ray tube, the central terminal and the left-leg electrode are connected to the second set of deflecting plates by way of a second amplifier adjusted to give a deflection 1.7* times as great as the first for the same input. The connections are so made that relative negativity of the central terminal produces a downward, and relative negativity of the left-leg electrode an upward, deflection.

 $[\]sqrt{3} = 1.73 +$

When these arrangements have been completed, the cardiac electromotive force displaces the luminous spot on the screen of the tube through a horizontal distance proportional to E cos α and through a vertical distance proportional to E sin α . Consequently, this spot always marks the terminus of the cardiac vector, and, as this vector varies in magnitude and direction, it moves along a continuous curve until the cardiac electromotive force becomes zero, when it returns to its isoelectric position at the center of the screen. This curve may be photographed with a camera of the ordinary type by opening the shutter just long enough to record a single heartbeat. Time is measured along the curve. It may be recorded by placing an alternating voltage of the desired frequency upon the grid of the tube. When this is done, the continuous curve is broken into segments each of which represents a known interval of time.

This method has several important advantages over others which might have been employed to the same end. One of its chief advantages is that most of the equipment is of a standard type and may be used for many purposes other than the study of the vectorcardiogram. This equipment consists of a commercial cathoderay oscillograph of the kind which is supplied with a separate terminal for each of the four deflecting plates, two amplifiers which will give sufficient voltage amplification without distortion of the electrocardiographic deflections, a device by means of which a standardizing voltage of 1 mv. may be introduced into the input circuit of either amplifier, and resistors for the network described, which may also be used to advantage in taking precordial and esophageal leads. We have used a 5 in. tube with a time delay screen which gives a brilliant spot and a pronounced afterglow, which makes it possible to see the path followed by the spot for several seconds. Tubes of the high vacuum type seem to give better definition than those of the low vacuum type. The two amplifiers which we have used are of different kinds. One is a three-stage push-pull direct current amplifier which gives a voltage gain of 25 to 30 thousand. The second is a three-stage push-pull amplifier with resistancecondenser coupling between the stages. This amplifier will give a voltage amplification of 100,000 or more and has an over-all time-constant of nearly 3 seconds, so that distortion of the slower electrocardiographic deflections is negligible. We hope to improve our technique by replacing the direct current amplifier with a second amplifier of this type, which will make it possible to use greater amplification when the voltage of the electrocardiographic deflections is small, and to obtain more satisfactory vector diagrams of the P and T deflections.

RELATIONS BETWEEN THE VECTORCARDIOGRAM AND THE STANDARD LEADS

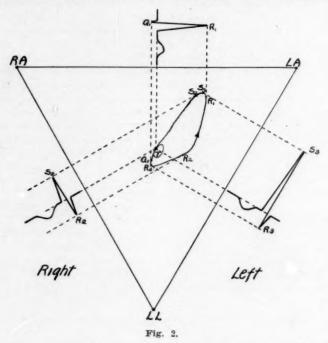
The diagram shown in Fig. 2 illustrates the relations between the vectorcardiogram and the standard limb leads. In this diagram the center of Einthoven's equilateral triangle coincides with the isoelectric point of the curve enclosed by it, and the projections of this point upon the sides of the triangle coincide with the isoelectric levels of the three leads. These leads are shown in their proper orientation and the points on the curve which correspond to their chief peaks are indicated.

It will be noted that Leads II and III are inverted. It would, of course, be possible to avoid this by reversing the polarity of the vertical component of the cardiac vector, but this cannot be done without violating the convention established by Einthoven, who represented the heart's electromotive force by an arrow pointing in the minus-plus direction or from the active toward the resting muscle. This convention has been

universally accepted, and it should not now be abandoned. The potential value of the vectorcardiogram depends upon the possibility of obtaining from it information regarding the spread and retreat of the excitatory process which cannot be obtained from the standard limb leads without the expenditure of an excessive amount of time and labor. This information will be obtained more easily if the customary method of representing the orientation of the electrical axis or cardiac vector is followed.

OBSERVATIONS

The vectorcardiogram of a normal subject is shown in Fig. 3. The movements of the spot which represent the P- and T-waves are very



small and their details are lost in the uniformly black area which surrounds the isoelectric point. The large closed loop represents the QRS complex. At the time when the photographs were taken, it was noted that the luminous spot traversed this loop in the clockwise direction. In other words an observer who followed the path of the spot would find the enclosed area constantly on his right. Following the usual mathematical convention, we shall speak of the areas enclosed by loops of this kind and of the loops themselves as negative; whereas, when the motion of the spot was counterclockwise, we shall refer to the loop inscribed as positive. The observation made with reference to the direction of motion of the spot is confirmed by comparison of the vectorcardiogram and the standard leads which are also reproduced. Since there

is a definite S deflection in Lead I, the terminal part of the loop must lie to the right of the isoelectric point. A good idea of the velocity of the spot in various parts of its course may be gained from the curves obtained when the grid potential, which controls the beam current of the cathode-ray tube, was made to oscillate 100, 200 or 1,000 times per second. These curves show that the QRS interval was about 0.07 or 0.08 second, and that the spot moved much faster during the earlier than during the later portions of this period.

It should be mentioned that the apparatus used in taking the vector-cardiogram was adjusted to give a horizontal displacement of 10 mm. and a vertical displacement of 17 mm, when a millivolt was impressed upon the input circuits of both amplifiers. After this adjustment had

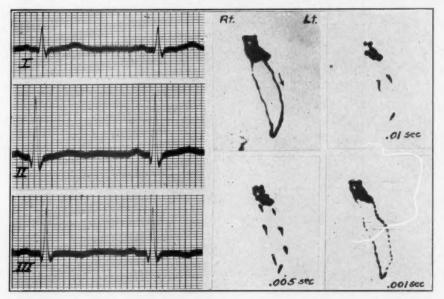


Fig. 3.

been made the accelerating voltage of the cathode-ray tube was frequently reduced in order to obtain larger curves. Measurements of the vectorcardiograms reproduced in this article cannot, therefore, be expressed in millivolts except by comparison of the dimensions of these curves with the voltages of the deflections of the standard leads.

Some years ago Lewis reported that left ventricular preponderance and the common type of bundle branch block were both characterized by an almost uniform counterclockwise rotation of the electrical axis during the QRS interval.* In right ventricular preponderance and bundle branch block of the rare type, on the other hand, clockwise rotation of the electrical axis was found to occur. Lewis based his conclu-

^{*}In the case of bundle branch block only those deflections written during the first half of this interval were analyzed.

sions upon the analysis of a relatively small number of electrocardiograms, and we hope to extend his observations. For the present we shall merely indicate how the vectorcardiogram may be used for this purpose by describing a few curves obtained from cases of the kind which he studied.

A good example of vectoreardiograms obtained when the standard leads show left axis deviation is shown in Fig. 4. In this instance the QRS interval is 0.11 or 0.12 second. It is possible that a defect in intraventricular conduction was present, but the QRS loop shows none of the peculiarities in contour which that condition often produces. This loop is of the positive variety. Throughout the greater part of the QRS interval the cardiac vector rotated counterclockwise. Near the end of this interval its magnitude gradually decreased, but its direction re-

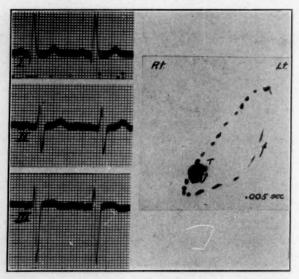


Fig. 4.

mained nearly constant. At -50° this vector attained its greatest length. The T-loop is also positive. The cardiac vector rotated counter-clockwise during its inscription. The inclination of the longest vector of this loop cannot be determined accurately, but it is obvious that it is separated from the maximal QRS vector by an angle of considerably less than 180° .

A second example of left axis deviation is shown in Fig. 5. Here the maximal QRS vector lies between -15° and -20° and the greatest T vector points in the opposite direction. The QRS interval is well within normal limits. The larger of the two areas enclosed by the QRS loop is positive; the smaller, which is near the isoelectric point, is negative. The cardiac vector did not rotate through a very wide angle, but such rotation as occurred was mainly counterclockwise.

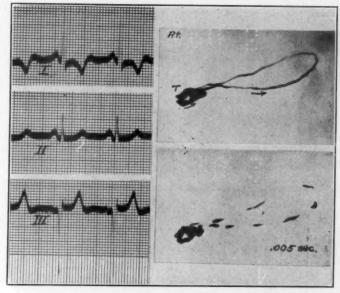


Fig. 5.

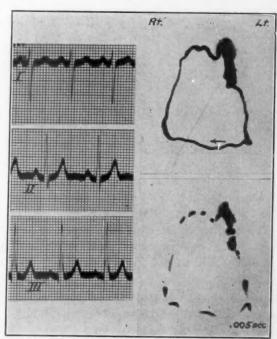


Fig. 6.

The vectorcardiogram obtained in a case of right axis deviation is shown in Fig. 6. The QRS interval is approximately 0.08 second. The area enclosed by the QRS loop is negative and very large. During the inscription of this loop the rotation of the cardiac vector was mainly clockwise, but at the beginning of the QRS interval and again at the end a temporary reversal in the direction of its rotation took place. It should be noted that it is necessary to distinguish between the direction taken by the spot during the inscription of the QRS loop and the direction in which the electrical axis rotates during the same period. If the luminous spot continues to move in the same general direction it may execute an S-shaped curve, such as occurs near the isoelectric point in

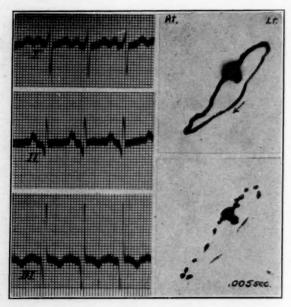


Fig. 7.

the present instance. During a period of this kind the electrical axis swings first one way and then the other, but turns through a relatively small angle. The cardiac vector reached its maximum length when its inclination was +120°. It was, however, already near its maximum magnitude when at +75°. During the inscription of T the amount of rotation was very slight.

A second example of right axis deviation is shown in Fig. 7. Here again the area enclosed by the QRS loop is negative, but it is relatively small. The cardiac vector rotated clockwise through an angle of approximately +180°. During the first part of the QRS interval its inclination was about -50°; during the last part and at the time when it reached its greatest length its inclination was about +125°. The T

loop is very small and cannot be made out clearly. The $\rm R_1$ and $\rm Q_3$ peaks were nearly synchronous, as were also the $\rm S_1$ and $\rm R_3$ peaks.

In bundle branch block the vectorcardiogram is often very bizarre in outline. Both the rotation of the cardiac vector and its changes in magnitude may be strikingly irregular. Beading of the curve, and accessory loops are common.

An example of left bundle branch block is shown in Fig. 8. The main QRS loop is positive, but the small accessory loop at about -30° is negative and is conspicuously beaded. There is also a beaded projection in the neighborhood of -60° . These irregularities correspond to the deep notches which deform the QRS complex of the standard leads.

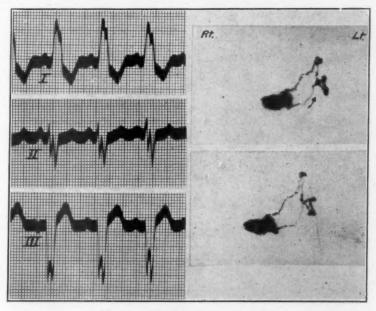


Fig. 8.

Beads occur when for a short period the magnitude and direction of the cardiac vector remain nearly constant. Loops are produced when the cardiac vector temporarily reverses the direction of its rotation, and at the same time undergoes a transient reduction or increase in magnitude.

The left bundle branch block curve shown in Fig. 9 is of a different form. The cardiac vector rotated counterclockwise through a relatively small angle. It reached its greatest length when its inclination was -60°. There is considerable beading of the QRS loop, but there are no accessory loops and the QRS complexes of the standard leads are not conspicuously notched. The direction of the maximal T vector is almost exactly opposite to that of the maximal QRS vector.

A curve which depicts an interesting example of right bundle branch block is shown in Fig. 10. During the inscription of the QRS loop the rotation of the cardiac vector was counterclockwise, but during

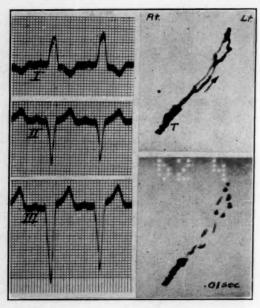


Fig. 9.

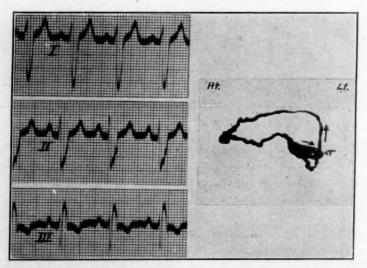


Fig. 10.

the inscription of the T loop it was clockwise. There is considerable beading of the QRS loop, but it is confined largely to the region of the tip inscribed at the time when the magnitude of the vector was maximal

and its inclination approximately -170° . The patient was a young man who presented typical signs of Fallot's tetralogy.

Another somewhat unusual case of right bundle branch block is illustrated in Fig. 11. The main QRS loop is positive; the beaded acces-

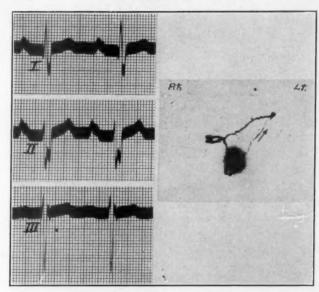


Fig. 11.

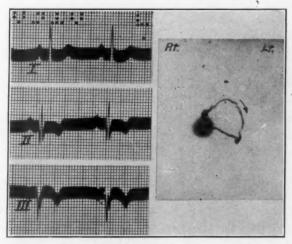


Fig. 12.

sory loop which corresponds to the deep notch seen in the QRS complex of Lead II is negative. The inclination of the largest QRS vector is approximately -60°, as in some cases of left bundle branch block. The patient was a young woman with congenital heart disease. Autopsy disclosed the presence of a huge ostium primum in the auricular septum.

Evidently, the cardiac vector may rotate counterclockwise in right bundle branch block as well as in left.

Fig. 12 illustrates the appearance of the vectorcardiogram in a case of infarction of the diaphragmatic wall of the heart. During the first part of the QRS interval, and also during the last part, the cardiac vector pointed almost straight upward. During the remainder of this interval it rotated clockwise and inscribed a loop which closely resembles the outline of a leaf. At the time when it attained its greatest length its inclination was about +30°.

COMMENTS

Our limited experience with the vectorcardiogram does not warrant any conclusion as to its ultimate usefulness. Nevertheless, it may be worthwhile to point out some of the ways in which it may possibly be utilized to advantage in teaching, in cardiac diagnosis, and in research.

In teaching it should prove helpful in the presentation of a variety of subjects. In this field it possesses advantages similar to those offered by vector methods in physics and mechanics. It makes it possible to visualize the electromotive force of the heart as a single natural entity unobscured by the artificiality and the complexities introduced by splitting it into a system of components in the arbitrary frame of reference defined by the standard leads. The importance of this difference will be easily appreciated if the vectorcardiogram is used to study the effects produced by the rotation of the heart which takes place on deep inspiration. Instead of the complicated changes which take place in the form of the ventricular complexes of the three leads one sees a simple clockwise rotation of the whole curve accompanied by very minor changes in its form due to twisting of the heart on its long axis. The vectorcardiogram can hardly fail to make it easier for the student to grasp the relations between the three standard limb leads, the reason why homonymous peaks in the different leads are frequently asynchronous, the meaning of axis deviation, and the manner in which notching of the QRS complex depends upon irregularities in the growth and decline and in the changes in direction of the cardiac electromotive force.

It is more difficult to foresee what advantages the vectorcardiogram may bring to the field of cardiac diagnosis. It is unlikely that it can offer important help in the identification of the arrhythmias, or in the measurement of the P-R, QRS, and Q-T intervals. It is possible, on the other hand, that it may aid in the detection and the differentiation of abnormalities in the form of the ventricular complex. It is true that by expending a great deal of time and effort one may derive the vectorcardiogram from the standard electrocardiogram, or vice versa, and that the two are in this sense equivalent. It is likewise true that mere inspection of the standard electrocardiogram will often enable one

to predict the general contour of its vector counterpart and to infer the general direction of rotation of the cardiac vector and its approximate inclination at the time when it reaches its greatest length. This is not possible in all instances, and there must be many in which the vector-cardiogram will furnish data which could not be obtained from the standard leads without excessive labor, if at all. In future studies we hope to determine whether the vectorcardiogram will help to differentiate between axis deviation due to simple rotation of the heart and axis deviation due to right or left ventricular enlargement, or between abnormally large Q deflections in Lead III due to elevation of the diaphragm and similar deflections due to infarction of the posterior wall of the heart. We hope to determine also whether it will help in the detection of minor defects in intraventricular conduction which do not increase the QRS interval beyond 0.10 second.

As a tool in research, Einthoven's method of determining the direction and magnitude of the cardiac electromotive force has been of much less value than might have been anticipated. It was employed with success by Einthoven and his associates in a study of the effect of changes in the position of the heart upon the form of the electrocardiogram. Lewis attempted to correlate the direction of rotation of the electrical axis with the order of activation of the muscle of the contralateral ventricle in bundle branch block. This study and a similar investigation in which he attempted to explain how preponderant hypertrophy of one ventricle produces characteristic changes in the form of the ventricular complex seemed for a time so well-founded as to defy criticism. Subsequent events have shown, however, that many of his conclusions cannot be accepted. It is apparent that the method is one that must be used with due regard for what it can and what it cannot be expected to accomplish. We agree with Lewis that the direction of the cardiac vector at a given instant during the QRS interval and the direction in which the excitatory process is spreading through the ventricular muscle at the same moment are very nearly if not exactly the same. When one attempts, however, to make use of this principle he is faced with a great many difficulties. One of the most serious is the lack of much more complete knowledge than we now possess regarding the spread of the excitatory process over the cardiac muscle. Another difficulty arises from the circumstance that the cardiac vector is a resultant; it is the vector sum of a great many components concerning which it gives us no information. It may well be that none of these components has the same direction as their sum, and consequently that no part of the cardiac muscle is undergoing activation in the direction which the cardiac vector defines. We are handicapped also because we are dealing solely with those components of the heart's electromotive force which lie in the plane defined by the three standard leads. In spite of these difficulties, it is possible that the vectorcardiogram may help us to learn more about

the origin of the electrocardiographic deflections and of the changes in form which they display in various types of cardiac disease. should like to point out that it may be used in studying the relations between the QRS complex and the T deflection. It is clear that if the excitatory process were uniform in all parts of the ventricular muscle, so that the order of ventricular activation and the order of ventricular deactivation were identical, the direction of rotation of the cardiac vector during the inscription of the QRS loop and the direction of its rotation during the inscription of the T loop would necessarily be the same. When one of these loops is positive and the other negative, as in Fig. 10, it is evident that the form of T was not purely a consequence of the form of QRS, but was determined in part by local variations in the excitatory process.

SUMMARY

The cathode-ray tube affords an easy means of recording the magnitude and direction of the electromotive force produced by the heartbeat throughout the cardiac cycle. A method employed for this purpose is described. The curves obtained by this method are vector functions of the time and may be called vectorcardiograms. A number of different ways in which these curves may prove useful in teaching, in cardiac diagnosis, and in research are discussed.

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MEASUREMENT OF CIRCULATION TIMES AND THE AGENTS USED IN THEIR DETERMINATION*†

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SINCE the early work of Blumgart and his associates (1927),¹⁻⁵ increasing attention has been given to the determination of the velocity of blood flow. Fundamentally, measurement of the velocity of blood flow, or circulation time, requires the introduction of a foreign substance into the blood stream at one point and the subjective or objective perception of the time of its arrival at another part of the body. Blumgart,⁶ Tarr and his associates,⁷ and Fishberg⁸ have reviewed in detail the steps in the development of this procedure, beginning with Harvey's description of the circulation of the blood.

In 1927 Blumgart, Yens, and Weiss^{1, 2} described the use of a radium salt for measuring blood velocity. Their method was entirely too expensive and complicated for ordinary use and could not be repeated oftener than every four hours. Weiss, Robb, and Blumgart⁹ attempted to measure the velocity of blood flow with histamine hydrochloride. This test, however, was accompanied at times by severe reactions and could not be used in patients with cardiac disease, in negroes, or in patients with severe anemia. Lian and Barras,^{10, 11} in 1930, reported their observations with fluorescein and explained the clinical applications of the test. Kohler and other European observers began to use calcium chloride but found that leakage of this substance into the subcutaneous tissue caused sloughs. Attempts were also made to use sodium cyanide,¹² but this method, like that involving the injection of a radium salt, is objectionable because of its lack of simplicity.

A step forward was made in 1933, when Tarr, Oppenheimer, and Sager⁷ improved on the method that Winternitz, Deutsch, and Bruell used in Germany. This consisted of the intravenous injection of a 20 per cent decholine sodium solution. The method was simple and merely required the measurement of the time elapsing from the beginning of the injection until the patient noticed a bitter taste. Later that year, Fishberg, Hitzig, and King¹³ used soluble saccharin, the end point of this test being the appearance of a sweet taste. In 1935 Hitzig^{14, 15} went even further and, with the introduction of the ether test, enabled us for the first time to measure with ease, both subjectively and objectively, the circulation time from the antecubital veins to the pulmonary capillaries.

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[†]The 20 per cent Calcium Gluconate used in this study was made available through the courtesy of Sandoz Chemical Works, Inc., in the form of Neo Calglucon.

Goldberg, ¹⁶ in 1936, suggested calcium gluconate as a means of measuring the circulation time; with this substance the end point is a hot feeling in the back of the tongue and throat. Table I lists the different normal circulation times obtained by various observers.

TABLE I

OBSERVERS		METHOD	DISTANCE MEASURED	RANGE (SEC.)	AVER- AGE (SEC.)
Blumgart, Weiss ²	1927	Radium C	Arm to arm	15-24	18.0
Lian, Barras10, 11	1930	Fluorescein	Arm to arm		30.0
Weiss, Robb, Blumgarto	1929	Histamine	Arm to face	13-30	23.0
Bartels, Powelson19	1929	Histamine	Arm to face	15-25	
Robb, Weiss ¹²	1933	Sodium cyanide	Arm to carotid	9-21	15.6
Tarr, Oppenheimer, Sager ⁷	1933	Decholine	Arm to tongue	10-16	13.0
Fishberg, Hitzig, King ¹³	1933	Saccharin	Arm to tongue	9-16	
Lian, Facquet17	1936	Saccharin	Arm to tongue	8-16	
Webb, Sheinfeld, Cohn20	1936	Saccharin	Arm to tongue		10.7
Goldberg16	1936	Calcium gluconate	Arm to tongue	10-16	12.5
Spier, Wright, Saylor21	1936	Calcium gluconate	Arm to tongue	7-22	14.6
Baer, Slipakoff	1937	Saccharin	Arm to tongue	9-16	12.6
Baer, Slipakoff	1937	Calcium gluconate	Arm to tongue	9-16	12.7
Blumgart, Weiss2	1927	Radium Č	Pulmonary circu- lation	5-17	10.8
Robb, Weiss ¹²	1930	Sodium cyanide	Crude pulmonary time	7-14	10.6
Blumgart, Weiss ²	1927	Radium C	Arm to right heart	2-14	6.7
Hitzig14	1935	Ether	Arm to lung	3-8	5.5
Webb, Sheinfeld, Cohn20	1936	Ether	Arm to lung	4-8	6.3
Lian, Facquet17	1936	Ether	Arm to lung	4-8	
Baer, Slipakoff	1937	Ether	Arm to lung	4-8	5.7

A review of the subject indicated that the saccharin, calcium gluconate, and ether methods should be simplest and most accurate. It was therefore decided to repeat some of the observations previously made and to compare the agents used in determining the circulation time in human beings. All of the objective methods used thus far have the distinct disadvantage of being dangerous, too complicated, or too difficult to perform at the bedside.

PROCEDURE

The experiments were performed on patients in the medical and obstetric wards, on private patients, and on patients in the cardiac, allergic, and pulmonary outpatient departments.

Each patient was made to lie in bed, and the test was not begun until the pulse and respiratory rates reached basal levels. The saccharin arm-to-tongue test was then performed, with some slight modifications of the method described by Fishberg, Hitzig, and King.¹³ Rather than prepare the material anew each time a test was done, 55 gm. of powdered pure saccharin were dissolved in 50 c.c. of sterile distilled water and introduced under aseptic precautions into a rubber-stoppered sterile vial. Some of the saccharin in this solution crystallized upon cooling, but it was readily redissolved just before use by placing the vial in warm water. This preparation was stable and could be used repeatedly. After heating it to body temperature, 2.5 c.c. were drawn into a 5 c.c. syringe. With the arm at the level of the right auricle (5 cm. below the plane of the manubriosternal junction), the

solution was injected with an 18-gauge need into the antecubital vein. The circulation rate was timed by a stop watch, from the beginning of the injection to the first moment a sensation of sweetness was noticed on the back of the tongue.

Following this, with the needle remaining in the vein, a syringe containing 5 c.c. of 20 per cent calcium gluconate was inserted into the needle. The intravenous injection of 2 to 3 c.c. of calcium gluconate causes a sudden sensation of heat in the back of the throat and tongue. The feeling of heat then spreads to the face, abdomen, perineum, and extremities. The injection is timed from the second it is begun to the instant the sensation of heat is felt in the throat. Duplicate readings were usually made with the remainder of the 5 c.c.

Finally, with the same needle in situ, or by another venipuncture, the ether arm-to-lung time was determined. This test was originally described by Hitzig14 and modified slightly by Miller.²² A mixture of 5 minims of ether and 5 minims of saline is injected intravenously; the end point is the perception of ether vapor in the upper respiratory passages. Almost invariably the patient will cough or denote by his facial expression the presence of the ether. This test is objective as well as subjective, for the observer close to the patient recognizes the odor as promptly as the patient does.

All circulation rates are recorded in seconds and are timed by stop watch from the beginning of the injection to the moment the end point is recognized.

REACTIONS

It might not be amiss to consider the question of reactions to these tests. The literature has contained references to the possibility of serious reactions accompanying the intravenous administration of calcium gluconate, but no death has been reported incidental to its use in studying the circulation time. In our series of approximately 150 injections of 2 to 5 c.c. of 20 per cent calcium gluconate, we observed but one reaction. The initial injection of calcium gluconate in a case of myocardial infarction (Case 109) was productive of severe precordial pain. In no other case was a similar occurrence noted. Saccharin is likely to cause pain in the arm when it is injected outside the vein, and a number of patients develop thrombosis of the injected vein. Leinhoff²³ reported a severe antecubital inflammatory process lasting five weeks that resulted from the perivascular infiltration of saccharin.

The injection of ether produced a creeping feeling along the course of the vein, particularly if the same vein had been used for the saccharin test. Hitzig¹⁵ advised against introducing saccharin and ether into the same vein because of the increased number of thromboses and the greater local pain. Leinhoff²³ reported a fatality accompanying the injection of 2.5 c.c. of 10 per cent ether in saline. He doubted whether the test alone was the cause of death but felt that it was a precipitating factor.

CIRCULATION TIMES IN VARIOUS CONDITIONS

Normal Circulation Times.—In Table II are listed the circulation times of 21 patients having no known cardiac or pulmonary disease. Tests 1, 19, and 45 were performed on a patient in the maternity ward.

Greenstein and Clahr²⁴ and Cohen and Thomson²⁵ have shown that despite some minor variations the circulation time during pregnancy falls within normal limits. These determinations were therefore included among the normal times.

TABLE II

CASE	DIAGNOSIS	ETHER	SACCHARIN	CAL. GLUC.	SACCHARIN ETHER DIFFERENCE	CAL. GLUC. ETHER	ECG	COMMENTS
1	Pregnancy	5.2	1	14.0		8.8	Normal	Twins; dyspnea;
13 16 19 (1A)	Acute pyelitis Pregnancy (Post	6.0	15.0	12.5 15.0	11.0 9.0	7.5 9.0	Normal	double mitral mur- mur Fever, tachycardia Pyelitis Chest clear, no dyspnea
24		5.0	7.5	11.0	2.5	6.0		Anasarca; no dyspnea
30	Ulcerative colitis				8.0	7.0		Diarrhea
32	Renal calculus		12.0		6.0	9.0		Urinary symptoms; obesity; dyspnea on effort
40	Ulcerative colitis	8.0	15.5	14.0	7.5	6.0		Diarrhea
45	Pregnancy	5.0	12.0		7.0			No congestive signs
(1B)	(Post partum)	5						
49	Colitis	4.7	11.0	10.0	6.3	5.3		Diarrhea
60	Nephritis	5.0	13.0	10.0 10.5	8.0	5.2		Urinary changes
61	Gastrointestinal study	5.0	13.0	12.0 14.0	8.0	8.0		Gastrointestinal symptoms
62	Acetanilid poisoning	7.0		16.0		9.0	Normal	Extreme cyanosis
83	Diabetes mellitus	5.0	8.0	8.0	3.0	3.0	Myocar- dial de- pression	Suggestion of basal râles
84	Carcinoma of stomach	5.0	14.0	15.0	9.0	10.0	•	No congestive signs
85	Pyonephrosis	8.0		16.0		8.0		No signs of cardiac disease
105	Polycystic kidneys	5.0		11.5		6.5		No congestive signs
121	Duodenal ulcer	6.0		12.0 12.0		6.0		
122	Buerger's disease	5.0	13.0		8.0	6.0	Normal	No cardiac signs or symptoms
131	Empyema of gall bladder	9.0		13.5 14.0		4.7	Normal	No congestive signs
134	Gastrointestinal study	6.0		15.0 15.0		9.0		No congestive signs
21	Average	5.7	12.6	12.7	7.1	7.1		
ases								

The ether arm-to-lung time is an index of the functional activity of the right heart.^{14, 15} In 20 of the 21 measurements the circulation time varied between 4.1 and 8 sec., with an average of 5.7 sec. In only 3 of the group did it deviate from the average by more than 1.5 sec. The end point was always sharp and in no case did we fail to get an accurate, clear-cut result.

The saccharin and calcium gluconate tests both measure the time required for the injected material to pass from the point of injection to the tongue. Since the blood velocity from the aorta to the tongue is very rapid, the difference between the ether time and arm-to-tongue time is an accurate index of the rate of flow through the left heart. This estimation of the left heart time is one of the best methods available for measuring the velocity of pulmonary blood flow.

In 30 determinations of the normal saccharin and calcium gluconate times, the range was 9.0 to 16.0 sec., as found by Fishberg, Hitzig, and King, 13 Oppenheimer and Hitzig, 26 and Goldberg. 16 The average for saccharin was 12.6 sec., for calcium gluconate, 12.7 sec. All but 3 of the determinations fell within the normal range, and repeated tests rarely varied more than 0.5 to 1.0 sec. The average left heart time was 7.1 sec., irrespective of whether saccharin or calcium gluconate was used. In Cases 24 and 83, the total circulation times were more rapid than normal. Causes of increased velocity of blood flow will be discussed later in this paper.

Circulation Time in Pulmonary Disease.—In Table III are listed determinations of circulation time in 20 patients having acute or chronic lung disease with no known cardiac complications. The circulation times were normal in all except 4 cases. One patient, a 17-year-old girl with massive recurrent empyema (Case 48), had a rapid circulation time. Hitzig15 stated that when the circulation is obstructed in one lung, the circulation time is either rapid or in the low normal limits. Three patients (Cases 53, 54 and 99) had prolonged circulation rates. The first two had chronic tuberculosis and emphysema, and the last was a 60-year-old man who had suffered from hay fever for twenty-seven years. With these few exceptions, the left and right heart times were normal in pulmonary disease unaccompanied by cardiac changes. Oppenheimer and Hitzig26 pointed out that uncomplicated pulmonary insufficiency is usually attended by normal circulatory measurements. They found no parallelism between the severity of clinical symptoms and the slowing of pulmonary blood flow. Even in their patients with pure right heart failure the clinical symptoms appeared out of proportion to the degree of retardation of circulation through the lungs.

Circulation Times in Cardiovascular Disease.—Table IV includes over 200 circulation times measured on 78 patients with known or suspected cardiac disease. Blumgart and Weiss³ stated that prolongation of the circulation time almost invariably indicated the presence of congestive heart failure. Tarr, Oppenheimer, and Sager¹ found the average velocity of blood flow for patients with congestive failure to be 26 sec., which is just double the normal average.

Of the 78 patients whom we studied, 25 showed some prolongation of the ether time. In 20, or 80 per cent of these, there was definite evidence of right-sided heart failure. Of the remaining 5, one had

auricular flutter, 2 auricular fibrillation, and 2 heart block. According to Hitzig¹⁵ and others, the ether time is normal with few exceptions, unless there is evidence of right-sided cardiac insufficiency.

In this group of 78 cardiac patients, 37, or almost 50 per cent, showed some prolongation of the left heart time, and there was no definite corre-

TABLE III

CASE	DIAGNOSIS	ETHER	SACCHARIN	CAL. GLUC.	SACCHARIN ETHER DIFFERENCE	CAL. GLUC. ETHER	ECG	COMMENTS
17	7 Pyopneumo-	5.0	13.0	11.1	8.0	6.1	1	Unilateral function-
33	thorax Lung abscess	7.0	15.0	13.0	8.0	6,0		ing lung Cough, expectoration hemoptysis; no râles
48	Empyema	2.5	8.0	7.5	5.5	5.0		Dyspnea; cough
	Tuberculosis	10.0			5.0	3.5		Dyspnea; cough
	Pulmonary tuberculosis	9.0			12.0		-	Dyspnea; also had emphysema
65	Acid fast contact	7.0	12.0	10.0	5.0	3.0		Cough
68	Pneumonia	6.0	14.0	9.0	8.0	3.0		Pain, cough, fever
92	Bronchial asthma	5.0		8.0		3.0		Chest clear
93	Bronchial asthma	5.0		9.0		4.0		Râles; dyspnea
94	Bronchial asthma	6.0		10.0 13.0		5.5		Râles, whines, dysp- nea
95	Bronchial asthma	6.0	18.0		12.0	10.0		Normal during tests
96	Bronchial asthma, emphysema	6.0	11.0	1	5.0	8.5		Few râles
97	Sinusitis, asthma	6.0	15.0	11.5 13.0	9.0	6.5		Râles at bases
98		5.0	15.0 16.0	13.0	10.5	8.0		Râles between attacks
99	Acute asthma	7.0	21.0	16.0 20.0	14.0	11.0		Dyspnea; hay fever,
100	Bronchial asthma	5.0	12.0	9.0	7.0	4.0		Status asthmaticus
102	Bronchial asthma	5.5		11.5 13.0		6.8		Râles, wheezes
110	Lobar pneu- monia	4.0	16.0		12.0	7.0		Physical signs of pneumonia
119	Bronchial asthma	5.0	9.0	9.0	4.0	4.0	Normal	Râles
120	Tracheobron- chitis	5.0	11.0		6.0	6.5		Chest clear
Ave	erage	6.1	14.1	11.5	8.1	5.9		

lation between this prolongation and the clinical aspects of their disease. In their study of the circulatory dynamics in myocardial infarction, Fishberg, Hitzig and King^{27, 28} showed that the circulation time may be normal despite the presence of extreme shock, dyspnea, and cyanosis. We have repeatedly obtained normal measurements in cases of myocardial infarction.

TABLE IV

CASE	DIAGNOSIS	ETHER	SACCHARIN	CAL. GLUC.	SACCHARIN ETHER DIFFERENCE	CAL. GLUC. ETHER DIFFERENCE	ECG	COMMENTS
2	Complete heart	18.0		55.0		37.0	Heart block;	Heart failure;
3		14.2		85.2		71.0	severe myo- cardial disease Myocardial	Anasarca; ex-
4	Sympathico- tonia	5.2	9.8	12.8	4.6	7.6	failure Tachycardia	treme dyspnea Flushes; dysp- nea; tachy- cardia; loss of
5	Mitral stenosis	5.4	9.8	9.8	4.4	4.4	Normal	weight Fatigue; dysp-
6	Arteriosclerotic heart disease	12.2	23.0 22.0	32.0	10.5	19.8	Myocardial disease	nea at times Dyspnea on
7	Cardiac failure	19.0	26.0		7.0		Auricular fibrillation, myocardial disease	effort Cyanosis; dysp- nea, ascites; venous stasis
	Cardiac failure	11.0	24.0		13.0			Obvious cardiac
(3A)	Hypertension	9.2	17.3	14.3	8.1	5.1	Normal	failure Dyspnea on effort
10	Emphysema; heart failure	14.0	25.0	32.4	11.0	18.4	Left axis devia-	
11	Neurocircula- tory asthenia	5.0	11.2	9.4	6.2	4.4	Left axis devia-	Precordial pain
12	Congenital heart disease	6.0	11.0	8.5	5.0	2.5	Sinus arrhythmia	Mod. dyspnea on effort
14	Coronary artery disease	7	35.0	25.0			Myocardial disease	Hypertension; râles, precordial
15	Myocardial in- farction	5.0	$26.0 \\ 22.0$		19.0		Auricular flut- ter	Cyanosis, tachy- cardia
18	Arteriosclerotic heart disease	8.0	35.0	26.0	27.0	19.0	Healed myo- cardial infarc- tion	Cyanosis, dysp- nea, râles
20	Severe mitral stenosis	12.0	?	9				Dyspnea, numer- ous râles
21	Auricular fibrillation	15.0	26.0		11.0		Auricular fibrillation	Dyspnea; hyper- tension; râles, edema of feet
22	Mitral valvulitis	12.5	27.0		15.0		Auricular fibrillation	Dyspnea; cough; wheezes
23 (7A)	Cardiac failure	10.0	20.0	23.0	10.0	13.0	Auricular fibrillation	Cardiac failure less than on previous test
25	Hypertension, diabetes	5.0	15.0	12.0	10.0	7.0	Coronary sclerosis	No congestive signs
26	Hypertensive heart disease	5.0	15.0	11.0	10.0	6.0	Normal	Precordial pain; dyspnea
27	Hypertension	7.0	13.5		6.5		No evidence of myocardial disease	
28	Mitral stenosis	10.0	26.0	21.0	16.0	11.0		Occasional dysp- nea, no râles
31	Diabetes	7.0	30.0	26.0	23.0	19.0		Râles in chest; loss of ap- petite; ab- dominal pain

CASE	DIAGNOSIS	ETHER	SACCHARIN	CAL GLUC.	SACCHARIN ETHER DIFFERENCE	CAL, GLUC. ETHER DIFFERENCE	BOG	COMMENTS
	Arteriosclerotic heart disease	9.0	30.0			14.0	Severe myo- cardial dis- ease	No congestive signs; dyspnea
35	Rheumatic en- docarditis	. 5.0	15.0	11.0	10.0	6.0	Right axis deviation	on effort Precordial pain
36	Coronary artery disease	7.0		14.0		7.0		No congestive signs
37	Aortic and mitral stenosis	8.0		14.0		6.0		Marked kypho- scoliotic chest deformity
38	Coronary oc- clusion	5.0	28.0	28.0	23.0	23.0	Myocardial in- farction	
39	Myocarditis	7.0	40.0		33.0		Heart block; severe myo- cardial dis- ease	Orthopnea, râles, pleural effusion
	Hyperthyroid- ism			18.0 20.0	16.0	9.0	Auricular fibrillation	Râles at bases
43	docarditis			13.5	9.0	8.0	Normal	No congestive signs
	Rheumatic en- docarditis	11.5	18.5	19.0	7.0	7.5	Suggestive of rheumatic en- docarditis	Dyspnea; no de- compensation
46	Arteriosclerotic heart disease	6.0	35.0	26.0	29.0	20.0	Normal	Dyspnea; pal- pitation; edema
47	Arteriosclerotic heart disease	9.0	17.0	14.0	8.0	5.0	Left axis devia-	Dyspnea, pre- cordial pain
50	Coronary disease	6.0	23.0	15.5	17.0	9.5	Severe myo- cardial disease	Precordial pain;
52	Auricular fibrillation	8.0		20.0		12.0	Extrasystoles	Dyspnea; pal- pitation
55 56	Thyrotoxicosis Arteriosclerosis	6.0 5.5	13.0 16.0	21.0 12.0	7.0 10.5	15.0 6.5	Normal Myocardial dis- ease	Palpitation Dyspnea; pre- cordial pain
57	Rheumatic fever	5.2		10.0		4.8	Tachycardia	No congestive signs
58 (52 A)	Auricular fibrillation	6.6	22.0		16.4		No myocardial disease	Anemia; dysp- nea on effort
59	Hypertension	5.0	12.0	11.0	7.0	6.0	Coronary sclerosis	No congestive signs
63	Rheumatic carditis	7.0		23.0	16.0		Auricular fibrillation	Cardiac failure
66	Hypertension	8.0	18.0	21.0	10.0	13.0	Myocardial dis- ease	Dyspnea on effort
	Coronary sclerosis	8.0		13.0		5.0	Myocardial dis- ease	
69 (15 A)	Coronary oc- clusion	7.0	21.0	13.5	14.0	6.5		No evidence of failure
70	Coronary oc- clusion		20.0		16.0		farction	No evidence of failure
	Coronary disease		30.0		21.0		sclerosis	Bradycardia
	Rheumatic en- docarditis		10.0		4.0			Normal
74	Mitral stenosis	8.0	54.0	45.0 43.0	46.0	36.0	Auricular fibrillation; intraventricu- lar conduction defect	Dyspnea on minor effort

TABLE IV-CONT'D

CASE	DIAGNOSIS	ETHER	SACCHARIN	CAL. GLUC.	SACCHARIN ETHER DIFFERENCE	CAL. GLUC. ETHER DIFFERENCE	ecg	COMMENTS
7		4.0	12.0			6.0	Coronary	No congestive
70	pectoris Tachycardia	15.0	34.0	25.0	19.0	10.0	sclerosis	signs Dyspnea; râles
77	7 Myocarditis	5.0	13.0	15.0	8.0	10.0	Normal	in chest No congestive
82	2 Cardiac disease	14.0	38.0	28.0 22.0	24.0	12.0	Myocardial dis	signs - Dyspnea; râles; old coronary occlusions
86	Hypertension		10.0	10.0	6.0	6.0	Myocardial dis-	Precordial pain
87	heart disease	4.0	18.0	14.0 16.0	14.0	11.0		No signs of de- compensation
88	regurgitation	6.0		16.0 16.0		10.0	Normal	No congestive signs
89	Coronary oc- clusion	8.0	20.0	16.0 24.0	12.0	12.0	Coronary oc- clusion	Dyspnea; cyanosis
90	Possible coro- nary occlusion	7.0	15.0	15.0 13.0	8.0	7.0	Normal	Few râles on ad- mission
101		8.0		$25.0 \\ 26.0$		17.5	Myocardial disease	Dyspnea on moderate effort
107	Rheumatic en- docarditis	7.0		$15.0 \\ 18.0$		9.5	Myocardial dis- ease	No congestive signs
109	Coronary oc- clusion						Acute occlusion	Severe pain on injection of calcium
111	Hypertension	8.5		$12.0 \\ 14.0$		4.5	Negative	Precordial pain
112	Myocarditis	7.0		14.0 14.0			Myocardial dis- ease	signs
	Hypertension	6.0		10.0			Myocardial dis- ease	signs
115	clusion		9	15.5 16.5	10.5		Acute infarc- tion	Precordial pain
	Coronary oc- clusion	14.0		22.0 26.0	22.0		Acute infarc- tion	No congestive signs
117	Sciatica	11.0		20.0	16.0		Myocardial dis- ease	Râles at bases
123 (16 A)	Coronary oc- clusion	14.5	18.5	18.0 18.0	4.0	3.5	Coronary oc- clusion	Precordial pain
	Arteriosclerotic heart disease	8.0	16.0	15.0	8.0	7.0	Myocardial dis- ease	Râles at bases
125	Arteriosclerosis	8.5	16.0	15.0 18.0	7.5	8.5	Myocardial dis- ease	No signs of de- compensation
127	Coronary oc- clusion	6.0		14.0 14.0		8.0	Coronary oc- clusion	Pain
	Cardiac failure	10.0		32.0 34.0	35.0	23.0	Severe myo- cardial disease	Râles in chest
	Coronary oc- clusion	7.5		$\begin{array}{c} 20.0 \\ 22.0 \end{array}$		13.5		Râles; ascites
128	Cardiac failure	10.0		31.0		21.0	Severe myo- cardial disease	Râles; dysp- nea
A) 136	Healed coro-	7.0	- 1	14.0		7.0		Pain in chest
137	nary occlusion Hypertension	8.0		$14.0 \\ 16.0 \\ 16.0$		8.0	sion Slight myo- cardial disease	Dyspnea; no

Table V presents further interesting data. Among 46 patients having prolonged circulation times, 33, or more than 70 per cent, showed some evidence of circulatory insufficiency, but only one, or 3 per cent, of 32 patients with normal circulation times had evidence of pulmonary congestion. When circulation times and electrocardiograms were compared, it was found that more than 80 per cent of cardiac patients

TABLE V

	NUMBER		VIOUS ILURE	CO	IONARY NGES- TON		SPNEA		ORMAL ECG.
Prolonged left and right heart times	23	15	65%	1	4.3%	7	30.7%	19	82.0%
Prolonged left heart time only	22	12	54%	4	18.0%	6	28.0%	19	85.0%
Prolonged right heart time only	1	1	100%					1	100%
Normal circulation times	32	0		1	3.1%	20	60.2%	15	45.5%

TABLE VI

CASE 41	DIAGNOSIS	ETHER	SACCHARIN	CAL. GLUC.	SACC. ETHER DIFFER.	CAL. GLUC. ETHER DIFFERENCE	BCG	COMMENTS
41	Hemiplegia, polycythemia	6.0	20.0	18.0	14.0	12.0		Hemiplegia; no congestive signs
71 (41A)		13.0	27.0	20.0	14.0	7.0		Hemiplegia; cyanosis
80	Toxic goiter	5.0	10.0	9.9	5.0	4.0		No congestive signs
81	Gastric ulcer	6.0	25.0 ?	$18.0 \\ 25.0$	19.5	15.5		Poor myo- cardial tone; dehydration
91 (81A)	Gastric ulcer	6.0	25.0 ?	13.0 20.0	19.0	10.5	Suggestion of myo- cardial disease	No congestive phenomena
106 (41B)	Polycythemia	7.0		18.0 16.0		10.5		Markedly cyanotic
129	Hyperthyroid- ism	5.5	9.0	8.0 9.0	4.5	4.0	Tachy- cardia	No congestive signs
135	Hyperthyroid- ism			8.0 9.0				Nervousness; tremors

with prolonged circulation times showed electrocardiographic changes indicative of myocardial disease. Of the patients with normal circulation times only 45.5 per cent showed similar changes.

Other Causes for Abnormal Circulation Times.—A few patients with abnormal circulation times had no obvious heart disease (Table VI). Tests 41, 71, and 106 were performed at various times on a patient with polycythemia and hemiplegia. The prolongation of the circulation time was undoubtedly due to the polycythemia, for similar observations have

been made by Blumgart, Cowgill and Gilligan,²⁹ Tarr and his co-work-ers,⁷ Webb and his co-workers,²⁰ and Hitzig.¹⁵

The circulation time also parallels the basal metabolic rates. Blumgart⁶ showed that the velocity of blood flow was strikingly increased in thyrotoxicosis and slowed in myxedema, and others^{7, 20, 30, 31} have reported similar observations. Goldberg¹⁶ used the calcium gluconate time as a test for hyperthyroidism. In three cases of hyperthyroidism (Cases 80, 129, and 135), we found the arm-to-tongue times rapid or in the low normal range. It has been suggested⁷ that a normal circulation time in the presence of undoubted clinical signs of heart failure should make one search for factors tending to increase the velocity of blood flow. Tarr, Oppenheimer and Sager⁷ found that the average decholine time in cases of hyperthyroidism with failure was 13 sec.

Other causes for an increase in the velocity of blood flow have been reported. A rapid ventricular rate may at times be associated with a definite increase in the velocity of pulmonary blood flow.⁶ Kopp³² found that the induction of therapeutic fever caused an increased circulation time. Averbuck and Friedman³³ reported that the saccharin arm-to-tongue time was somewhat more rapid in children than in adults. Ellis³⁴ found that exercise increased the velocity of blood flow, and others^{16, 7, 29} have reported a rapid circulation time in patients with anemia.

Tests 81 and 91 remain for consideration. They were performed at different times on a 43-year-old man who was supposed to have a peptic ulcer. Though no definite myocardial insufficiency could be found, the arm-to-tongue times were prolonged. Operation and incomplete postmortem study later revealed linitis plastica and very severe atheromatous changes in the aorta.

DISCUSSION

Apparently the most satisfactory method of measuring the velocity of blood flow is by the ether and calcium gluconate methods.

In the studies on normal patients and those presenting uncomplicated pulmonary disease (Tables II and III), there is a satisfactory correlation between the arm-to-tongue times as obtained by the calcium gluconate and saccharin methods, but this is not the case in those with cardiac disease (Table IV). The saccharin time in this later group was frequently from 3 to 10 sec. longer than the calcium gluconate time. The discrepancy was most marked in those cases showing prolonged circulation rates, perhaps due to the sharper end point obtained with calcium gluconate.

There remain for our consideration some of the clinical applications of those procedures. Table V shows that approximately 30 per cent of cardiac patients with prolonged circulation times did not have obvious heart failure. Some were not examined in detail because of our

unwillingness to disturb patients with acute myocardial infarction. Perhaps more careful study would have revealed the presence of some degree of circulatory embarrassment. But it is precisely in this group that measurement of the circulation time is most instructive. Blumgart and Weiss^{4, 35, 36, 37} pointed out that retardation in the velocity of blood flow may precede clinical evidence of heart failure. Hitzig¹⁵ showed that the ether time may be prolonged in certain cases of left heart failure with incipient right heart failure. A number of cases can be cited from our records in which prolongation of the circulation time predicted the onset of cardiac failure. For example, a patient (Case 15) had acute myocardial infarction. A circulation test which was performed while he had auricular flutter but seemed perfectly compensated revealed a definite prolongation of the left heart time. The following day he developed obvious signs of extreme circulatory embarrassment (cyanosis, edem., orthopnea, and bilateral pleural effusion).

These tests can be used to detect not only the onset, but also the type, of circulatory failure. This is of considerable practical value, for, as Fishberg, Hitzig and King²⁸ have pointed out, the ability to differentiate between right and left heart failure is necessary if patients suffering from myocardial infarction are to be treated rationally.

Webb, Sheinfeld, and Cohn²⁰ have measured the circulation rates in a large number of surgical cases and found that those patients with prolonged circulation times were poor operative risks and had a high operative mortality rate. They used the test also in differential diagnosis of cardiac, pulmonary and intraabdominal disturbances, but these results must be interpreted with caution, for in many cases of myocardial infarction and severe myocardial disease the circulation times are normal while the patient remains in bed. It must be remembered that the circulation time test is only a measure of the velocity of blood flow; obviously, it cannot tell us how much work the heart can do.

All in all, we believe that the measurement of arm-to-lung and arm-to-tongue times leads to more accurate diagnosis, particularly of cardiac and pulmonary disease, as Oppenheimer and Hitzig²⁶ and Weiss and Kleinbart²⁸ have shown. The value of the procedure in studying anemia and disturbances of metabolism has already been mentioned.

SUMMARY AND CONCLUSIONS

The ether arm-to-lung time of 21 patients with no evidence of cardio-vascular disease ranged from 4 to 8 sec., with an average of 5.7 sec. Normal saccharin and calcium gluconate arm-to-tongue times varied from 9 to 16 sec., with an average of 12.6 and 12.7 sec., respectively. The normal left heart time averaged 7.1 sec.

Circulation times in 20 patients suffering from uncomplicated bronchial or pulmonary disease fell within normal limits.

The presence of a normal circulation time almost invariably precluded the existence of congestive heart failure.

More than 70 per cent of 46 cardiac patients with prolonged circulation times showed evidence of circulatory insufficiency. Only 1, or 3 per cent, of cardiac patients with normal circulation times had pulmonary congestion.

Polycythemia vera caused a retardation and hyperthyroidism an increase in the velocity of blood flow.

The measurement of the circulation time is an effective aid in the early diagnosis of heart failure and in the differentiation of cardiac from pulmonary and other diseases."

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CALCAREOUS AORTIC VALVE STENOSIS

WITH PARTICULAR REFERENCE TO ITS ETIOLOGY*

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NO AGREEMENT has been reached as to the etiology of that pathologically characteristic lesion, calcareous aortic valve stenosis. The possible causes which have been suggested are (1) rheumatic fever, (2) arteriosclerosis, (3) healed subacute bacterial endocarditis, and (4) inflammatory or degenerative endarteritis of the vessels of the aortic valve ring.

We have encountered thirty-nine hearts with this lesion in a series of nine hundred consecutive autopsies. Seventeen of these hearts showed uncomplicated nodular calcification of the aortic valve leaflets; this series is designated below as series U. In twenty-two of these hearts there were varying degrees of pathologic involvement of the other valves (designated below as Series C). Sufficient consistent pathologic and clinical differences were found between these two small series to indicate a different pathogenesis for each.

PATHOLOGIC DATA

The presence of some degree of stenosis, with calcification, of the aortic valve was the original, sole criterion for selecting the hearts. In twelve of the seventeen uncomplicated cases comprising Series U the lesion was fully developed, with nodular masses of calcium markedly deforming the aortic valve and protruding into the sinuses of Valsalva. Less complete, less advanced lesions were found in the aortic valves of the other five hearts of Series U. In two of these valves two of the three leaflets were calcified and fused. In another valve the anterior cusp stood out as a single, calcified plaque, and the other two leaflets merely had a few small nodules at their bases. In two hearts the calcium deposits were confined entirely to the base of the aortic valve leaflets; the edges of the leaflets were thin.

In eleven (50 per cent) of the hearts in series "C" the marked calcification and stenosis of the aortic valve were indistinguishable from the twelve uncomplicated, fully developed lesions in Series U. The valves of the three additional hearts, all from patients over 70 years of age, resembled the five incompletely calcified valves found in Series U, i.e., the calcification was located primarily at the base of the valve leaflets.

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However, in the remaining eight hearts of Series C, in which there was incomplete calcareous aortic valve stenosis with mitral valve lesions, the character of the aortic valve lesions was significantly different. In four the calcification was confined either solely or predominantly to the free edge of the leaflets; in three it was diffusely and irregularly scattered throughout the leaflets; and in one it was in superimposed vegetations on the valve leaflets.

The complicating mitral valve lesion in Series C consisted in four instances of slight thickening of the free edge of the leaflets; nine hearts showed grossly thickened leaflets without significant stenosis; and nine showed definite mitral valve stenosis. In eleven instances there was calcification in the deformed mitral valve leaflets. Three hearts of Series C also showed some deformity of the tricuspid valve.

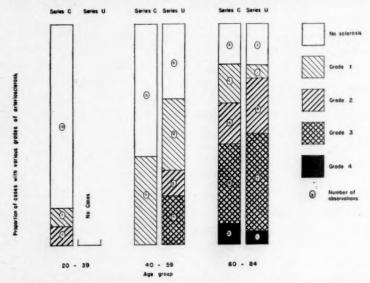


Fig. 1.—Showing the various grades of generalized arteriosclerosis in different age groups in patients with calcareous aortic valve stenosis. Series U, uncomplicated. Series C, complicated by lesions in other valves.

Pericardial adhesions were present in only two cases in Series U and in eight in Series C. In the latter series the pericardial sac was completely obliterated in two; in four the adhesions were very numerous; and in two there was but a single adhesion band.

Splenic infarcts, old or recent, were found in only four cases, all of which were in Series C.

To evaluate the amount of generalized arteriosclerosis present, the observations on the degree of arteriosclerosis of the coronary arteries and aorta were graded on an arbitrary scale of zero to four. Each observation was given equal weight in order to limit the number of categories into which a comparatively small number of observations (78) would be divided. Fig. 1 shows the proportion of the various

grades of arteriosclerosis in each age group of the two series. The usual increase in the amount of arteriosclerosis with age is shown in both series. Within each separate age group, however, there was more arteriosclerosis in the individuals with calcareous aortic valve changes unaccompanied by mitral valve changes (Series U) than in the corresponding individuals in Series C.

CLINICAL DATA

The sex and age distribution of these patients is shown in Table I. Among the seventeen patients in Series U there were only two women; in Series C there were eleven men and eleven women. In Series U no patients were under 40 years of age at death, and only three (18 per cent) were under 50, but in Series C eleven patients (50 per cent) were under 50 years of age.

A typical history of rheumatic fever was elicited from fourteen of the thirty-nine patients. Of the group of twenty-two patients with mitral valve involvement (Series C), thirteen gave such a history. The rheumatic fever history in the patient without mitral valve disease was not characteristic.

TABLE I
DISTRIBUTION BY AGE AND SEX

YEARS	Ul	SERIES U	TED		SERIES C	D
	MALE	FEMALE	TOTAL	MALE	FEMALE	TOTAL
20-29	0	0	0	3	1	4
30-39	0	0	0	1	1	2
40-49	2	1	3	2	3	5
50-59	6	0	6	0	0	0
60-69	3	0	3	3 -	0	3
70-79	3	1	4	2	. 5	7
80-89	1	0	1	0	1	. 1
Total	15	2	17	11	11	22

DISCUSSION

The single complication of changes in the margins of the mitral valve leaflets divided our originally selected series of hearts showing calcareous aortic valve stenosis into two groups; in one the valve deformity was probably of rheumatic origin, but in the other there was no definite evidence that the etiology was rheumatic. The many differences between the two series were striking enough to suggest that we were dealing with two essentially different pathologic entities. Fig. 2 summarizes graphically the major differences between these two groups. In neither group was there any clinical or pathologic evidence of previous bacterial endocarditis, or of underlying endarteritis of the aortic ring arterioles, both of which have been suggested as possible etiologic factors (Cabot, and Margolis and co-workers²).

Table II includes our cases, together with almost four hundred other previously reported cases of aortic valve stenosis. Definite aortic valve stenosis was present in all the cases, and, in at least some of the hearts, the valves were calcified. The reported series fell into four groups. The first group, corresponding to our Series U, includes those hearts in which there was absolutely no evidence of endocarditis of the mitral valve leaflets. In the second group some hearts might have shown slight thickening of the mitral valve leaflets. The third group is an obviously mixed group. In all of the cases of the fourth group, corresponding to our Series C, there was definite thickening of the mitral valve leaflets. In this entire collection the incidence in women and of a history of rheumatic fever increases, and the percentage of patients over fifty years of age decreases, as one proceeds from Group I to Group IV.

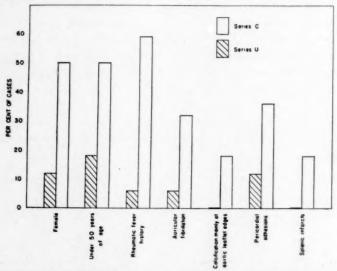


Fig. 2.—The major differences between the cases of uncomplicated calcareous aortic valve stenosis (Series U) and those of calcareous aortic valve stenosis complicated by changes in the mitral valve (Series C).

In view of the ready division of our own series into two groups with and without evidence of a rheumatic process, it was considered desirable to review the literature for evidence which might indicate that calcareous aortic valve stenosis is always due to rheumatic fever. There was a definite history of rheumatic fever in eleven (50 per cent) of Christian's twenty-two patients, but he also states that "in none were the tricuspid, mitral, or plumonic valves structurally abnormal except for occasional thickening of the leaflets." In Clawson's series, "rheumatism, as indicated by a positive history or by evidence of a previous pericarditis or by both, was present in 49 per cent of the 160 cases of the noncalcified group (of aortic stenosis), and in 40 per cent of the 93 cases of the calcified nodular valve deformity." He also adds that 38

REPORTED CASES OF CALCAREOUS AORTIC STENOSIS CLASSIFIED ACCORDING TO AGE, SEX, AND HISTORY OF RHEUMATIC FEVER TABLE II

			- A TOTAL OF THE PARTY OF THE P			HISTOI	HISTORY OF		CRITERIA		-
	TOTAL CASES IN SERIES	FEMALES	LES	OVER	20	RHEUMATIC	EUMATIC	AORTIC CALCIFICA-	NON- STENOTIC MITRAL	MITRAL	AUTHOR
		NO.	3%	NO.	%	NO.	0%	TION	LESION		
Group I	12	1	00	10	83	0	0	P*	A	A	Gibbs10
No cases in which there was thicken-	15	1	2	12	80	03	13	Д	A	A	Clawson
ing of mitral leaflet edges	17	63	12	14	85	-	9	Ъ	V	A	Series U
Group II	42	00	19	35	60	೧೦	2	Ь	Ι	V	Margolis ²
Possibly mixed series	45	19	20	34	92	90	18	Ъ	T	V	McGinn ⁶
	59			36	61			Д	,	V	Clawson4
	21	9	53	13	62	11	52	Ь	M	V	Christian ³
	28	00	0	15	54	14	20	Д	M	V	Cabot1
Group III	35	1-	20	16	46	6	26	M	A	A	McGinn ⁶
Probably mixed series	98	17	20	52	09	32	37	Ъ	M	M	McGinn ⁶
	93			49	53	46	49	Ь	M	M	Clawson4
Group IV	15	90	52	60	20	6	09	M	Ъ	M	Gibbs10
Il cases in which there was thicken-		11	20	11	20	13	59	Ъ	Ь	M	Series C
ing of mitral leaflet edges				13	38			Ъ	Д	M	Clawson4
)	50	21	42	11	22	22	74	M	Ы	Ъ	McGinne
	. 07	13	33	14	35			M	Д	Ь	Cabot1

*P, present in all cases; A, absent in all cases; M, mixed, present in some cases; and I, indeterminate, data insufficient.

patients (41 per cent) in the calcified nodular group had, in addition, acute or healed lesions of the mitral valve. In his previously reported series of fifteen cases (Clawson, Bell, and Hartzell⁵) in which there was an old, calcified, nodular deformity of the aortic valve, and, presumably, no abnormality of the edges of the other valves, there were only two patients with pericardial adhesions and two with histories of rheumatic fever.

Margolis and co-workers² elicited a history of "rheumatism" from but three of forty-two patients selected "on the basis of the existence, pathologically, of calcareous infiltration of the leaflets of the aortic valve in the absence of significant degrees of involvement of other valves." McGinn and White⁶ reported that a history of rheumatism was obtained in 18 per cent of forty-five patients with aortic valve stenosis without mitral valve stenosis. Hearts with nonstenotic mitral valve lesions are not mentioned as being excluded. However, a history of rheumatic fever was obtained in 74 per cent of fifty cases of aortic valve stenosis, both calcified and noncalcified, in which definite stenosis of the mitral valve was also present.

The data in other series are not in such form as to permit division into these two groups. In our series of thirty-nine patients, thirteen (33 per cent) had a definite history of rheumatic fever, and nine additional patients (23 per cent) had mitral valve lesions which might well have been of rheumatic origin. All our patients with histories of rheumatic fever also had mitral valve changes.

In a review of 411 cases in which death was caused by rheumatic heart disease, Davis⁷ found 198 hearts in which both the aortic and mitral valves were deformed, and only eighteen instances of pure aortic valve deformity. Thus, in but 8 per cent of a large number of hearts in which the aortic valves were deformed by rheumatic fever was the lesion confined to that valve. On the other hand, in Clawson's series⁴ of 93 hearts with calcareous aortic stenosis, 55 (59 per cent) presumably showed no mitral valve deformity. Also, in our series of 39 hearts, 17 (44 per cent) were without rheumatic mitral valve involvement. This high incidence of pure aortic valve lesions in hearts with calcareous aortic valve stenosis suggests that rheumatic fever cannot be the sole etiologic agent.

The high incidence of pericardial adhesions in patients with calcified aortic stenosis is repeatedly offered as additional evidence that the aortic valve lesion is of rheumatic origin. In our series, however, pericardial adhesions were common only in the cases in which there was accompanying mitral valve disease.

The location of the calcification in the aortic valve cusps has been used both to support and discredit rheumatic fever as the etiologic agent. In some instances the calcium is located principally at the free edge of the leaflet, and in advanced lesions the entire cusp is calcified. This is said to be consistent with changes subsequent to rheumatic fever. Mönckeberg,⁸ and Margolis and his associates² emphasize the fact that in hearts without mitral valve lesions the early calcification is at the base of the aortic valve leaflets. In those of our cases in which there were rheumatic mitral valve deformities, incomplete aortic valve calcification always involved only the free edges of the leaflets, but in those in which there was no mitral valve lesion, the incomplete aortic valve calcification invariably extended from the base of the leaflets. Thus another difference is established between the two groups.

Some workers^{9, 8, 10} regard arteriosclerosis as the most likely cause of calcified aortic valve stenosis. Others^{3, 4} maintain that such patients have less general arteriosclerosis of the aorta and coronary arteries than other individuals of the same age. Because of the vagaries in the distribution of arteriosclerosis, such an objection does not seem valid. Gibbs¹⁰ found a high incidence of arteriosclerosis of the aorta and renal arteries in his series. In our series the amount of generalized arteriosclerosis was roughly proportional to age. In general, more arteriosclerosis was found in the "uncomplicated" group than in the group in which there were associated mitral valve lesions, but this is very slight evidence that arteriosclerosis was the etiologic factor in the uncomplicated cases, and can be accepted only because all other possible causes were apparently excluded.

According to differences in the age and sex distribution, in the incidence of a history of rheumatic fever, of pericardial adhesions, of splenic infarcts, and of generalized arteriosclerosis, and from the location of the calcification in the earlier, incomplete lesions, cases of calcareous aortic valve stenosis can be divided into two groups: in one the lesion is rheumatic in origin and there is an accompanying deformity of the mitral valve, and in the other the lesion is uncomplicated and probably of arteriosclerotic origin.

SUMMARY

Seventeen cases of calcareous aortic valve stenosis without mitral valve deformity are compared with twenty-two cases of calcareous aortic valve stenosis in which there was an associated lesion of the mitral valve of rheumatic origin. Patients under fifty years of age, women, histories of rheumatic fever, and instances of pericarditis were scarce in the former group and numerous in the latter.

In the cases of pure aortic valve stenosis the calcification in the valves was most pronounced at the base of the cusps, whereas in some cases in the other group it was more marked at the free edges of the cusps.

A slightly higher incidence of arteriosclerosis of the aorta and coronary arteries was found in the cases of uncomplicated aortic valve disease.

Calcareous aortic valve stenosis is not always rheumatic in origin. In some cases the etiology of the lesion is probably of the nature of an arteriosclerotic degeneration.

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THE LAG-SCREEN BELT ELECTROCARDIOGRAM*

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THE need of instant and continuous viewing of electrocardiograms has always been apparent. We have designed and shall describe a simple and effective device which, when attached to the electrocardiograph, permits such continuous observation. This apparatus is portable, compact, durable, simple, adaptable to all electrocardiographs, and permits simultaneous photographic recording.

The apparatus has a moving, flexible, endless belt coated with material which phosphoresces when exposed to the light beam of the electrocardiograph. The to-and-fro motion of the beam at the viewing aperture is thus given a second dimension, and the familiar graphic form appears exactly as on bromide paper. When the viewing aperture is kept dark, the degree of phosphorescence on the moving translucent screen is sufficient to define exactly the wave form, and, inasmuch as the image is retained from 8 to 30 seconds, one may view strips from 6 to 20 inches in length, which is ample for comparisons of rhythm and wave form. A given point on the screen loses its phosphorescence before it passes again over the viewing aperture.

The major difficulties in developing the lag-screen belt were (1) to find the most suitable phosphorescent material and the means of applying it to the surface of a flexible belt; (2) to provide light of sufficient intensity to ensure good contrast; and (3) to preserve the conventional optical system and camera, so that the electrocardiogram might be viewed and photographed at the same time.

Our early experiences taught us that there was a wide discrepancy in the phosphorescent properties of minerals obtained from various sources. Laperiments with light of different wave lengths led us to the conclusion that the materials we used phosphoresce most actively with wave lengths between 3,000 and 6,000 angstroms, which covers the visible spectrum and a portion of the ultraviolet. The problem was simplified when it was found that ultraviolet light and a special quartz lens system were not necessary. From the long list of phosphorescent materials available we selected phosphorescent zinc sulfide crystals containing the impurities which are not only essential to the physical property of phosphorescence but also determine the color of the glow. The yellowish green and the yellow gave the best contrast. The material used must be selected as an individual lot; it may be obtained of

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scientific supply houses.* The crystals apparently retain their property of phosphorescence without demonstrable loss for months. It seems that the deterioration is much less than that of material subjected to the cathode ray.

We used 35 mm. motion-picture film for narrow belts and ordinary photographic film for wider ones, joining the ends together with Duco cement. We found that the best method of applying the mineral to the belt was to spray it on the softened, moist, gelatinous surface of the cleared film. The crystalline material adheres firmly on drying without loss of phosphorescent property and gives the optical effect of a beaded motion-picture screen. The coating may be made as thick as desired by painting the sprayed surface with a suspension of crystals in warm, clear gelatin. Further experiments proved that the lag, or persistence time of the image, depended on three factors: The character of the material; the thickness of the coating; and the amount of energy conveyed to it by the light beam. The range of the last two factors is limited. Increasing the thickness of the belt lessens its transparency and therefore hinders the passage of the activating light beam. Thicker belts lose flexibility and are apt to flake. There is also diffusion of light in the thicker belts so that increasing the intensity of the light is not a solution of the problem of securing better definition. Practically, there is a limit to the amount of light that can be reflected from the small galvanometer mirror. An increase in the area of the galvanometer mirror is not desirable, as it introduces distortion by lowering the frequency response of the galvanometer.

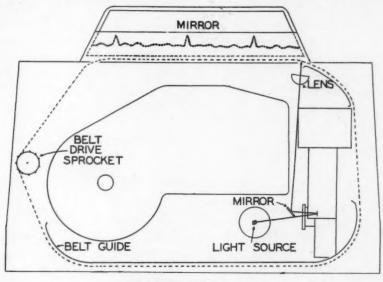
We have used automobile line focus light bulbs, motion-picture projector lamps, and the 85-watt, high intensity mercury-vapor lamp of the General Electric and Westinghouse Companies, with practically the same results. The mercury-vapor lamp has the advantages of extremely high intensity in the region of the shorter wave lengths of the visible spectrum and a low heat-light ratio, but it is much larger than the others, and requires a special alternating current transformer. Despite these disadvantages we have used it when long operation was required. This high intensity mercury-vapor lamp peaks at 3,650 angstroms, which permits the use of the standard optical glass lens system. A concentrating and reflecting lens of a high order of efficiency is essential, and there is little space for mounting such a lens in electrocardiographs of the General Electric type. First-surfaced reflectors are not essential, but they will increase contrast and permit the use of smaller, internally mounted, direct current lamps.

To permit simultaneous photographic recording at selected intervals during prolonged viewing with the lag-screen we have used a special light source with an angle of incidence and reflection which is different from that of the regular electrocardiographic optical system, but this

^{*}Pfaltz and Bauer, Empire State Building, New York City, N. Y.

does not impair the efficiency of either system; it is only a matter of changing to a one-light, split-beam arrangement. The use of the extra light permits photographic registration of a white beam and time lines, while on the lag-screen one sees a glowing line on a dark background.

Fig. 1 illustrates the method of building a lag-screen belt in a model "B" General Electric electrocardiograph; the construction of the case of this instrument lends itself ideally to this purpose. The belt emerges from the interior of the case at the viewing aperture in the right front portion, and passes along the black enameled surface to go over driving



FRONT VIEW

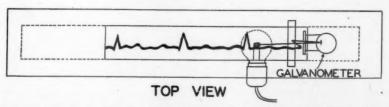


Fig. 1.—Diagram of the lag-screen belt installed in a portable electrocardiograph. The endless belt is shown passing through the viewing aperture over the surface of the top of the machine, where it is viewed in the mirror, thence over drive sprockets and guides. The viewing mirror is mounted in a light-trap. The top view shows the mirror system used for external light mounting.

wheels around the camera and the galvanometer. When so fitted, the belt is driven by the gears of the electrocardiograph motor, which is controlled as usual by the camera lever on the control board. The film drum within the camera is fitted with a drive which is engaged when a photographic tracing is desired.

The construction of a separate lag-screen viewing box necessitates passing the belt over rollers driven continuously by a synchronous motor.

A separate light source and a galvanometer actuated from the amplifier output, wired in parallel with the galvanometer of the electrocardiograph, are used. This separate unit is adaptable to machines now in use and simplifies simultaneous photography, for the camera motor may be started at any time during the viewing; the greater width of the lagscreen belt facilitates visualization in the classroom or operating room. For the larger system the most intense light source and the largest possible galvanometer mirror surface are used.

The cathode-ray lag-screen has been adapted to electrocardiography by Dr. Frank N. Wilson at the University of Michigan, and in the later commercial Dumont and Hindle instruments, but the large cathode-ray tubes which are required and the necessity of incorporating a slowsweep beam and an automatic base line changer which interrupts the waves make the instrument difficult to transport, complicated, and expensive. Contrariwise, the lag-screen belt attachment enables one to view longer strips without changing the control or galvanometer system, is inexpensive, and does not affect portability. When a light-trap carrying a mirror (Fig. 1) is placed above the belt the image is upright and extraneous light is excluded.

SUMMARY AND CONCLUSIONS

The inexpensive lag-screen belt attachment which we have described makes it possible to view the electrocardiogram while it is being recorded. Immediate visualization is useful in emergencies and in teaching, saves time and expense, especially when it is desirable to make observations over long periods (e.g., during surgical or obstetrical procedures), enables the clinician to follow and record rapid changes in the mechanism of the heart beat, facilitates differentiation of the various arrhythmias, and helps to estimate the effects of drugs. The lag-screen method is analogous to fluoroscopy; fine details, such as notching of the P-waves and minor changes in the form of the QRS complex, may be missed, but these disadvantages are more than offset by the fact that it gives us a great deal of valuable information quickly.

To Dr. Ralph H. Major, of the Department of Medicine, H. P. Cady, Ph.D., of the Department of Chemistry, and F. E. Kester, Ph.D., of the Department of Physics, University of Kansas; and Herman Schlundt, Ph.D., of the Department of Physical Chemistry, University of Missouri, we wish to express our appreciation for assistance and advice.

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OBSERVATIONS ON PASSIVE VASCULAR EXERCISE AND OTHER FORMS OF TREATMENT OF PERIPHERAL VASCULAR DISEASE*

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M ANY forms of therapy have been devised for peripheral vascular disease,1,2,3 especially for that which leads to occlusion of arteries. The development of apparatus for passive vascular exercise by Herrmann and Reid, and Landis and Gibbon, was hailed with considerable enthusiasm. Those who originated the method were optimistic about the results which they obtained from this form of treatment. Other observers, notably Wilson and Roome⁶ and Allen and Brown,⁷ have not been encouraged by their results. As with many kinds of therapy which exert a considerable psychic effect on the patient, the latter observers believed that direct benefit from the apparatus must be cautiously evaluated. Our observations, which were begun shortly after the introduction of passive vascular exercise therapy, were also discouraging, as will be pointed out later. Another difficulty in judging the efficacy of this form of therapy is that it has, in many instances, been combined with other measures which might influence the therapeutic result. The symptoms of peripheral vascular disease are frequently so urgent and troublesome that rigid adherence to any plan of controlled observation becomes almost impossible. Because of this difficulty, and the great confusion that now exists with respect to the treatment of peripheral vascular disease, experiments were devised with the hope that some light might be thrown on the methods of re-establishing the circulation in diseased and normal legs under different conditions.

EXPERIMENTS BY PERFUSION OF EXTREMITIES

Experimental studies were made on the extremities of individuals immediately after death. Just preceding death, one of the extremities was raised so as to empty it of venous blood, and the other was lowered over the side of the bed, or was subjected to a pressure of 40 mm. Hg by means of a blood pressure cuff in order to maintain a full venous system. By this manipulation it was possible to study the influence of venous pressure on arterial flow.

Immediately post mortem, cannulae were placed in the femoral arteries and femoral veins, the arterial cannula being connected to an "artificial heart" or a heart-lung preparation (Fig. 1). Defibrinated animal blood was perfused through the extremity. The inflow of blood into the extremities was measured by means of a volume recorder in the case of the artificial heart, and a mercury gauge in the

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case of the heart-lung preparation. In each instance a pulsatile pressure was used in order to simulate the pressures produced by a normally beating heart. Observations were made both on normal extremities and on those in which there had been clinical evidence of peripheral vascular disease.

RESULTS

In normal legs whose veins had been emptied ante mortem, difficulty was encountered in forcing the blood into the arteries, even when the procedure was attempted immediately. In such cases it was necessary to place a tourniquet around the leg and to elevate the venous pressure from 10 to 20 mm. Hg to re-establish a maximum arterial inflow. In normal legs whose veins were distended before death, no difficulty was

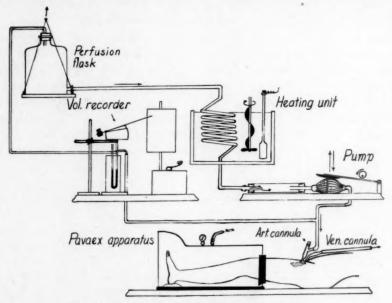


Fig. 1.—Diagram of the perfusion apparatus used.

encountered in passing blood through the extremity from the artery to the veins, unless sufficient time had elapsed after death to permit the blood to clot. The results for the normal extremity did not vary greatly from those established by other methods in man.⁸ The extremities of individuals with clinical disease of the peripheral arteries were more difficult to study. In the first place, it was not possible to obtain a calculated arterial inflow. Under these circumstances the greatest possible inflow was utilized, and the factors determining it were evaluated. Since the maximum inflow varied with each extremity, it had to be established for each one. Considerable difficulty was then experienced until it was discovered that passing hypertonic saline (5 per cent)⁹ through the vessels increased the blood flow immediately. It was found that when the perfusion of extremities of individuals with normal vascu-

lar trees was not begun until thirty or forty minutes after death, the difficulty was the same as that encountered when extremities with diseased arteries were perfused immediately after death. Only by passing hypertonic saline through the vessels could one obtain, or even approach, the normal calculated flow through the extremity. Since the only similarity between the two states was that the extremities had been deprived of oxygen, it was considered possible that the phenomenon was due to a reaction of degeneration. Increasing the arterial or venous pressure appeared not to influence the arterial rate of flow under these conditions.

It was assumed that the action of hypertonic saline in opening diseased vessels was attributable to dehydration of the capillary endothelium. Swelling of the capillary endothelial cells has been demonstrated as a reaction not only of degeneration, but at one time was suggested as a mechanism by which all capillaries were constricted.10 These experiments suggest that an elevated venous pressure exerts a favorable influence on the passage of blood through the arteries. This important fact had been previously considered in the treatment of peripheral vascular disease by Silbert¹⁶ and by Collens and Wilensky¹¹ and others.15, 17 It appears that in partial arterial obstruction the veins or venules may collapse, thus offering further obstruction to an already enfeebled circulation. Increasing venous pressure by application of a tourniquet to the limb permits a backflow into collapsed venules, causing them to distend and enhancing the passage of blood through the arterioles and venules. One may liken this mechanism to a valve which can only be opened by elevating the venous pressure.

In six other experiments on the same extremities, after the maximum blood flow had been established, the pavaex apparatus was placed over the leg. Usually the arterial inflow as well as the venous output was diminished during the negative phase of the cycle. In three experiments the machine caused a definite decrease in the total blood flow during the time that the boot was on the extremity. There was some variation of inflow of blood to both the normal and diseased extremities. Immediately after the negative cycle began, there was usually a slight increase in the arterial inflow; whereas immediately after positive pressure was applied, the outflow from the venous side was increased.

Studies on the extremities begun immediately after death seemed to indicate that there are two definite factors to be considered in the treatment of peripheral vascular disease. One, and perhaps the most important, is that of increased venous pressure. The pavaex machine satisfies the factor to some extent when the negative phase of the cycle is removed. It must be emphasized, however, that a blood pressure cuff, or a tourniquet can accomplish the same effect on venous pressure. A second important factor is dehydration of the vascular tree, presumably more especially of the capillary cells. Passage of hypertonic solu-

tions directly into the arteries in our experiments had a definite favorable influence on re-establishing the circulation, especially in diseased arteries.

CLINICAL OBSERVATIONS

The clinical material was divided into two groups. Twenty-five patients were treated primarily with the passive vascular exercise machine alone, and twenty-three others were treated according to the principles established by the experimental studies. The former were given no supplementary treatment except improvement of local and general hygienic conditions, and advice in all instances to discontinue the use of tobacco.⁶ Patients treated with the passive vascular exercise machine were received from both clinic and private sources. In addition to the usual physical examination and laboratory tests (urinalysis, blood count, and Kahn test), some were examined roentgenologically after thorotrast injections in the vessels of the extremity; others had routine studies, such as skin temperature tests before and after treatment, and oscillometric readings of pulsation in the extremities, in addition to a careful vascular history.

Method of Treatment in First Group.—The passive vascular exercise unit devised by Herrmann and Reid and made by the Taylor Instrument Company⁴ was usually employed, although the one devised by Landis and Gibbon⁵ was used in three cases. The negative pressures usually varied from -60 to -120 mm. of mercury, while the positive pressure was +20 mm. of mercury. The machine was run at two or three cycles a minute. The cuffs at the top of the boot were those described by Herrmann and Reid. Some difficulty was always encountered in maintaining airtight connections and at the same time preventing obstruction to the venous return. In some cases special cuffs were used.

Most of the patients were hospitalized for a portion of the time. This applied especially to those with ulcers of the feet. All patients receiving the treatment were given careful instruction about care of the feet and advised to abstain from the use of tobacco. Buerger's exercises 12 were usually used to supplement the treatment. None of the patients, regardless of their economic condition, received supplementary treatment until after 20 hours of therapy. After that, biweekly administration of 100-300 c.c. of 3 to 5 per cent saline intravenously was begun and, unless contraindicated, intravenous typhoid vaccine was given to induce hyperpyrexia.

Arteriosclerosis (Table I).—Seventeen cases out of the total of twenty-five were diagnosed arteriosclerosis. Of this group, most patients received more than fifty hours of pavaex treatment, some as much as one hundred hours. Four patients were perhaps slightly benefited during the active period of treatment, since they were able to walk farther without pain in the extremity and also with less numbness and tingling. In no case, however, was there complete disappearance of symptoms, nor was there any notable change in the oscillometric reading of the extremity. In some instances thorotrast injections were made and showed obstruction of the arteries, usually of the femoral artery, before treatment. When this procedure was repeated after treatment, no evidence of increased anastomosis could be demonstrated. In Case 11 the ulcer of the toe healed during treatment. The patient was in the hospital for one and a half months and at the same time received the very best of care. He was a farmer, and his feet were dirty before

therapy began. The improvement of general hygiene appeared to be an important factor in the treatment. He is the only patient in the entire series who showed definite improvement following the therapy.

Thromboangiitis Obliterans.—Eight patients with thromboangiitis obliterans were treated, and in two there was improvement, as evidenced by the ability to walk from two to four blocks farther without pain and with definitely less numbness and tingling in the extremity. The remaining nine patients showed minor improvement. In no case of this group was ulceration of the feet or gangrene of the toes benefited. In two cases it was made so much worse that the patients refused to have the boot treatment and were discharged from the hospital and went to a second hospital where the therapy was advised, tried, and discontinued. In each case the leg was amputated.

One patient with embolic obstruction of the femoral artery was treated. Because of the extreme swelling which had persisted, only

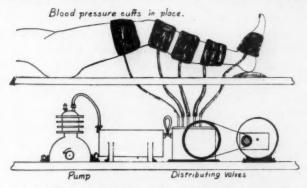


Fig. 2.—Diagram of the multiple blood-pressure cuff unit.

small pressure changes could be used and these did not effect any notable change in the extremity. The patient developed gangrene in spite of the therapy, which was then discontinued and a Sanders bed substituted, following the use of which the patient improved for a few days but died later from a cerebral embolus.

The results were very disappointing with any single method, especially with the pavaex machine. Our experimental studies had emphasized the apparent necessity for elevating the venous pressure in a diseased limb. To accomplish this, the following therapeutic measure was devised:

The treatment consisted of applying multiple (five) blood pressure cuffs to an extremity in order to maintain a high venous pressure. The pressure was about 40 mm. Hg for the cuff highest on the leg. Lesser pressures were applied to the succeeding cuffs, usually about 20 mm. Hg. The system was inflated and deflated every six minutes. The use of multiple cuffs appeared to shorten the total time that was necessary to maintain the venous pressure. We believe this was due to the fact that multiple cuffs tend to prevent distention of the superficial vessels of the

limb, 14 thus forcing the blood into the muscles and other deep tissues. The cuffs were usually applied two hours a day. Detailed reports of the machine will be made later.

Treatment of the Second Group.—This group (23 patients) was given treatment in which the venous pressure was elevated each day for two hours, as described above. Twice each week intravenous injections of 150 to 300 c.c. of 3 to 5 per cent saline solution were given, with due consideration for the general state of the individual's cardiovascular system. Intra-arterial injections have been avoided in arteriosclerosis where thrombi are expected because of the possible danger of breaking the thrombus free. The intra-arterial injections directed into the diseased artery in thromboangiitis obliterans appear to us to be more satisfactory than the intravenous saline injections. Hyperpyrexia, produced by the injection of typhoid vaccine, has been used in all our cases of thromboangiitis obliterans. The use of alcohol in the form of a highball before meals twice a day, in individuals with arteriosclerosis, has been substituted for fever therapy because of the relative danger of treating elderly patients with it, though in three of the younger patients with arteriosclerosis it was felt safe to use the vaccine.

Arteriosclerosis (Table II).—Twelve of the twenty-three patients were thought to have arteriosclerosis. All received about fifty hours of vascular congestion at the rate of two hours a day, five days a week. The effect of treatment in all of the individuals was to relieve pain and physical discomfort. It permitted those who were not otherwise handicapped to return to work, where they have remained for at least four months. There has been no tendency toward return of the symptoms to date. Two patients of the series could not be helped; any treatment caused severe pain in the extremity, accompanied by elevation in skin temperatures and greater volume of peripheral pulses.

Thromboangiitis Obliterans.—There were eleven cases of thromboangiitis obliterans. Each patient received from twenty to fifty hours of vascular congestion. The period of treatment was six months. The patient was instructed to discontinue tobacco in all forms.

The results obtained in this group of cases were most encouraging. Improvement began after the first week, and the capacity for normal physical activity returned within three months. Four patients stated that they had some numbness of the extremity throughout the five-month period. Three of the patients had rather severe ulceration of the feet which healed completely. All of them showed increase in pulsation of the peripheral arteries and often showed some increase in skin temperatures.

DISCUSSION

The great array of methods which have been devised to treat peripheral vascular disease indicates that each in itself may be insufficient. Recent reports and our own experience appear to place passive vascular

TABLE I
PATIENTS TREATED BY PASSIVE VASCULAR EXERCISE

CASE	AGE	HOURS	1 DAV	S SYMPTOMS AND SIGNS BEFORE TREATMENT	COMMENT ON CONDITION AFTER TREATMENT
				Thromboangiitis Obliterans	
1	55	11	11	I.C.* after walking 2 blocks. Obstruction high in left leg. No pulse in feet.	Temporary improvement
2	42	56	100		No change.
3	38	70	37	Pulse in both extremities poorly palpable. I.C. at 2 blocks.	No change.
4	50	51	40	Pain in foot at rest. Gangrene of 2 toes. No pulse. I.C. at ½ block.	Can walk 3 blocks with out pain. Rest pair about the same as be fore.
5	44	21	15	Paresthesia present on left foot which was cold. Pulse fair. I.C. at 3 blocks.	No change.
6	47	45	38	Pain on standing or walking. Pulse fair.	No change.
7	50	48	90	Cold right foot. Ulcer on toe. No pulse. I.C. at 2 blocks.	Less pain for a few weeks. Leg amputated.
8	45	15	72	Paresthesia at times for 2 years. Pulse fair. I.C. at 3 blocks.	Less paresthesia. Very little improvement.
0	00	0.5	18	Arteriosclerosis	77 / 1 7 7 /
9	68	25	15	Patient was diabetic. Great toe previously a m p u t a t e d. Wound slow to heal.	Foot unimproved, later amputated.
10	60	45	12	Pain in right foot at all times for 3 months. No pulse in	No relief.
11	58	50	40	foot or popliteal artery. Pain at rest in both feet. Ulcer in left great toe. I.C. at 2 blocks.	Ulcer improved as result of cleanliness in hos- pital.
12	67	42	33	I.C. at ½ block. Paresthesia over both feet. No pulse in either foot.	Paresthesia less. I.C. at 4 blocks.
13	52	22	14	Pain in right foot. Popliteal pulse absent.	Color of skin improved. Pain somewhat diminished.
14	72	108	37	Pain at rest. Feet cold and cyanotic. No pulse.	Pain at rest less. No obvious improvement otherwise.
15	67	82	25	Pain at rest. Ulcer on left large toe. Foot cold. No pulse.	Pain at rest more severe. No change in ulcer.
16	62	75	40	Left foot cold. No pulse. I.C. at 2 blocks.	Can walk 2 blocks.
17	73	24	7	Pain and swelling in right foot for 4 weeks. Foot cyanotic, cold. No pulse.	No change. Pain persisted during treatment.
18	56	109	35	Night pain while at rest. No pulse in foot. I.C. at ½ block.	Slight temporary improvement. I.C. at 3 blocks. Night discomfort persistent.
9	67	65	66	Patient a diabetic. Pain in feet at rest. Pulse weak. I.C. at 6 blocks.	No definite change no- table.
0 1	70	45	50	I.C. at 2 blocks. Paresthesia over dorsal and calf. No pulse. Feet cold.	Less pins and needles. No objective change. Able to work standing.
1 4	55	48	40 1	Ulcer on foot.	No improvement.
	57	50		Pain with exercise.	No improvement.
3 (61	36	45 1	Ulcer on foot. I.C.	No improvement.
	67	14		Thrombosis of left popliteal.	Pain increased. Amputation.
5 8	80	30	14 (langrene of left foot. Foot sloughed.	Pain less severe.

TABLE II

PATIENTS WITH ARTERIOSCLEROSIS TREATED BY MULTIFLE CUFF METHOD

CASE	AGE	HOURS OF TREAT- MENT	DAYS	SYMPTOMS AND SIGNS BEFORE TREATMENT	AFTER TREATMENT	SALINE 3 PER CENT 100-300 C.C. IN- TRAVEN.	HYPER- THEMIA LOCAL OR IV. TYPH.
1	60	55	,	I.C.* No pulse in rt. ft. or poplit. art.		12	Local
2	58	48	52]	Pain at rest, both feet. I.C. at 2 blocks.	Pain relieved. I.C. at 8 blocks.	12	8
3	67	52	80	I.C. at ½ block. No pulses both feet.	I. C. at 8 blocks. Pulses same.	15	8
4	52	38	40]	Pain rt. ft. No pulses, either ft.	Pain in rt. ft. disappeared.	10	7
5	62	58		Pain at rest. Ft. cyanotic. I.C. after few steps. Ulcer lt. gt. toe.	I.C. at 4 blocks. Rest pain gone. Ulcer healed.	20	
6	56	51	60 I	Pain at rest, both feet. I.C. ½ block.	Sl. improvement. Relief of rest pain.	8	Local
7	67	37		Diabetic, rest pain. Pulses weak. I.C. at 6 blocks.	Improvement questionable. I.C. continued. Mentally confused. Unable to state clearly.	3	Local
8	70	33		.C. at 2 blocks. Paresthesia over dorsum feet. No pulses.	Imp. No pain. Pulses present, but weak.	10	Local
9	55	52	90 T	Ticer on it. ft.	Ulcer healed. Cleanliness important factor in therapy.	7	Local
10	57	100	60 I	.C. at 2 blocks.	Imp. I.C. at 20 blocks.	dilute 1%	5 Local
11	72	45	35 P	ain. I.C.	Made worse. Block of nerves for re- lief of pain.	3	Local
12	64	140]	C. at 2 blocks. Night pain, rt. leg. Numbness.	Improved. Relapse. Received therapy again with im- provement.	12	10

^{*}I.C. is intermittent claudication; imp., improved; rt. and lt., right and left; ft., foot or feet.

exercise in this category. As Allen and Brown⁷ have reported, it may help to relieve the pain in asthenic neuritis, but this has been rather rare in our series. Some of the patients have been relieved of pain while their legs were in the machine, or during the first weeks after treatment

began, but on the whole there has been little if any definite improvement, either in the pain associated with vascular disease or in increasing the blood supply.

Landis and Hitzrot¹³ reported improvement in many of their patients with peripheral vascular disease, some of whom had diabetes, thrombo-

TABLE III
PATIENTS WITH THROMBOANGIITIS OBLITERANS TREATED BY MULTIPLE CUFF METHOD

CASE	AGE	HOURS OF TREAT- MENT	DAYS	SYMPTOMS SIGNS BEFORE TREATEMNT.	AFTER TREATMENT*	SALINE 3 PER CENT 100-300 C.C. IN- TRAVEN.	HYPER- THERMIA LOCAL OR IV. TYPH.
1	55	54	60	I.C.† at 2 blocks. No pedal pulses.	Improvement. I.C. at 25 blocks.	20	8
2	42	48	36	Painful gangrene gt. toe rt. foot. I.C. at 2 blocks.	Healing. Lost I.C.	14	7
3	38	48	50	I.C. at 2 blocks. Rest pain.	Lost I.C. and rest pain.	10	6
4	50	28	40	Pain both feet. I.C. at 1 block. Cyanosis.	Improvement. Lost I.C.	10	6
5	44	35	30	Paresthesia, lt. ft. Pulses good.	Lost paresthesia. Improvement in walking.	8	3
6	47	42	55	Pain at night. Cyanosis.	Improved. Lost night pain.	12	6
7	42	42	55	Pain at night. Large ulcer, rt. ankle.	Leg finally amputated.		
8	45	50	40	I.C. at 3 blocks, redness and pain.	Improved, can walk 20 blocks. Comfortable.	12	6
9	27	48	84	I.C. redness, Cyan.	Loss of redness. Comfortable.	22	10
10	47	20	120	Pain and redness.	Imp. Loss of pain. Some numbness.	8	5
11	39	44	60	I.C. pain, redness.	Complete healing.	22	10

^{*&}quot;After treatment" includes time patient was under treatment and several weeks

angiitis obliterans, and arteriosclerosis. They report relief of pain during the period of treatment with passive vascular exercise but do not record observations as to the permanent effects of the treatment on the pain. They were unable to convince themserves, however, that gangrenous or sloughing lesions improved with the treatment. Landis believed that intermittent claudication became milder and exercise tolerance was slightly but definitely increased. In our experience a certain

[†]I.C. is intermittent claudication; imp., improved; rt. and lt., right and left; ft., foot or feet.

amount of increase in exercise tolerance was obtainable because of the training of the patient with the type of apparatus used. Especially was this notable in an individual who was frequently tested from week to week; but, when it was discontinued for a period of a month or so, usually the increased exercise tolerance would diminish to approach the usual state. Most of our improvements in the first series might have been the result of abstinence from tobacco. All of the patients were or had been heavy smokers. In a few patients, who could not resist the use of tobacco, one could tell whether they had been smoking or not by occurrence of severe pain in the calf. It is felt that very little benefit is derived from the use of the passive vascular exercise machine.

SUMMARY

Twenty-five patients with peripheral vascular disease were treated with passive vascular exercise. There were seventeen cases of arteriosclerosis, and eight of thromboangiitis obliterans. Only a small degree of improvement was noted in any group aside from what we attributed to other forms of therapy. It is believed, from experimental and clinical studies, that three principles should be observed in the treatment of arteriosclerosis and thromboangiitis obliterans: (1) maintenance of a high venous pressure; (2) dehydration of diseased capillaries in order that the blood may pass through them; and (3) when necessary, stimulation of the heart and arterial side by hyperpyrexia or by the milder methods.

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THE BLOOD PRESSURE RESPONSE TO EPINEPHRINE ADMINISTERED INTRAVENOUSLY TO SUBJECTS WITH NORMAL BLOOD PRESSURE AND TO PATIENTS WITH ESSENTIAL HYPERTENSION*

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EVER since Oliver and Schäfer¹ (1895) discovered that epinephrine has a pressor effect, the possibility that it may be a factor in hypertension has been considered. Many have tried to prove that the vasomotor mechanism in patients with hypertension is abnormally sensitive to epinephrine, or that excessive amounts of epinephrine are present in the blood of these patients. New evidence in support of the latter possibility has recently been brought forward by Kuré, Nakaya, Murakami, and Okinaka,² who maintain that atropine has a beneficial effect in hypertension. Hetényi and Sümegi³ and Hess⁴ have presented experimental evidence that the vasomotor mechanism in patients with hypertension is abnormally sensitive to epinephrine, but their results were not corroborated by Kylin,⁵ Deicke and Hülse,⁶ Jansen,⁶ Gordon and Levitt,⁶ and Pickering and Kissin.⁰

The observations of previous investigators were made following rather rapid intramuscular or intravenous injection of relatively small doses of epinephrine. It occurred to us that it would be interesting to compare the effects of more prolonged intravenous injections of epinephrine on the blood pressure and pulse rate of persons whose blood pressure was normal and patients with essential hypertension. The results which we obtained form the basis of this report.

PROCEDURE

Each subject was made to lie quietly on a couch for thirty to sixty minutes before the experiment was begun. The anterior cubital vein was then punctured, and physiologic salt solution was allowed to flow slowly into the vein. When the blood pressure, pulse rate, and cutaneous temperature of the digits had reached a stable level, the plain salt solution was replaced by a dilute solution of epinephrine hydrochloride in physiologic saline (1:250,000). The shift was accomplished by using two burettes, one containing plain salt solution, and the other the epinephrine solution, both of which were connected to the needle in the vein by means of a Y-tube. At intervals of two to five minutes, over a period of fifteen minutees, beginning at the moment when the subjective effect of the epinephrine was first noted, the systolic and diastolic pressures were measured, the pulse rate counted, and the cutaneous temperature of the volar surface of the distal phalanges of several of the fingers and toes taken. Temperature readings were made with Sheard's electromotive

^{*}From the Division of Medicine, the Mayo Clinic. Received for publication Feb. 25, 1938.

thermometer.¹⁰ In some of the experiments a heat tent was placed over the subject's trunk forty-five to ninety minutes before the epinephrine injection was begun and was allowed to remain in position throughout the period of observation. The cold pressor test of Hines and Brown¹¹ was done on all of the patients with hypertension and on most of the normal subjects.

RESULTS

Experiments were performed on 12 persons whose blood pressure was normal and 10 patients with essential hypertension. The systolic pressure changes recorded represent the maximal increase above the resting level

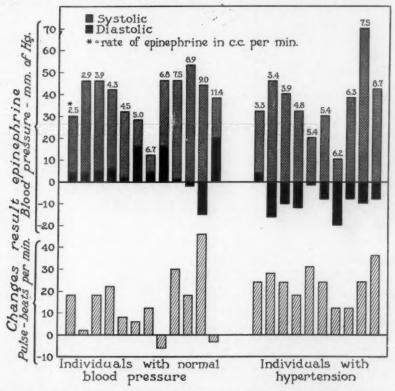


Fig. 1.—Graphic representation of response of blood pressure and pulse rate of normal subjects and patients with essential hypertension to intravenous injection, at varying rates, over fifteen minute periods, of dilute epinephrine solution (1:250,000).

during the fifteen-minute period, but, inasmuch as the diastolic pressures fluctuated both above and below the resting level, the changes recorded represent the maximal increase or decrease.

Tables I and II and Fig. 1 show that epinephrine had no more influence on the systolic blood pressure of patients with hypertension than on that of normal persons, that it usually lowered the diastolic pressure of patients with hypertension, and raised the diastolic pressure of the normal subjects. In the latter, the effect on the diastolic pressure was relatively less than on the systolic pressure. There was no visible cor-

TABLE I

Response of the blood pressure and pulse rate of subjects whose blood pressure was normal to intravenous injection, at varying rates, over periods of fifteen minutes, of dilute epinephrine solution (1:250,000); and the blood pressure response of the same subjects to the cold pressor test.

	1		OOD	-	OOD	PUL	SE RATE	EPI-	
CASE	AGE, YEARS	BEF	SURE ORE PHRINE	CHA	SURE NGE; LT OF PHRINE	BE- FORE EPI-	CHANGE; RESULT OF EPI-	NEPH- RINE INJEC- TION;	BLOOD PRESSURE RESPONSE TO COLD TEST
		SYS- TOLIC	DIAS- TOLIC	SYS- TOLIC	DIAS- TOLIC	NEPH- RINE	NEPH- RINE	RATE, C.C. PER MINUTE	
1*	40	82	56	+30	+ 4	84	+18	2.5	80/60 to 100/ 70
2	23	114	78	+46	+ 4	76	+ 2	2.9	
3*	40	90	60	+46	+ 5	72	+18	3.9	100/60 to 110/ 75
4*	24	108	72	+42	+ 6	84	+24	4.3	90/65 to 105/ 80
5	42	110	72	+32	+ 2	84	+ 8	4.5	
6	35	112	68	+28	+16	66	+ 6	5.0	
7*	47	134	90	+12	+4	78	+12	6.7	120/80 to 155/100
8*	30	106	70	+46	+16	72	- 6	6.8	
9*	45	104	60	+46	+ 4	54	+30	7.5	90/50 to 108/ 60
10*	58	125	85	+53	+ 3 - 7	72	+18	8.9	90/65 to 145/100
11	33	126	65	+44	- 15	60	+46	9.0	110/65 to 142/ 90
12	48	98	56	+38	+20	90	-12 + 6	11.4	115/75 to 168/120

^{*}Heat tent at 40 to 60°C. was placed over trunk forty-five to ninety minutes before injection of epinephrine was given. Tent was allowed to remain in position throughout the experiment.

TABLE II

Response of the blood pressure and pulse rate of patients with essential hypertension to intravenous injection, at varying rates, over periods of fifteen minutes, of dilute epinephrine solution (1:250,000); and the blood pressure response of the same patients to the cold pressor test.

			OOD	-	OOD	PUL	SE RATE	EPI-	
CASE	AGE, YEARS	BEI	SSURE FORE PHRINE	CHA RESU	SURE NGE; LT OF PHRINE	BE- FORE EPI-	CHANGE; RESULT	NEPH- RINE INJEC- TION;	BLOOD PRESSURE RESPONSE TO COLD TEST
		SYS- TOLIC	DIAS- TOLIC	SYS- TOLIC	DIAS- TOLIC	NEPH- RINE	OF EPI- NEPHRINE	RATE, C.C. PER MINUTE	TEST
1	41	:178	116	+32	+ 4	78	+24	3.3	170/120 to 235/155
2	28	152	88	+46	-16	84	+28	3.4	140/ 80 to 170/100
3	40	200	130	+40	-10	84	+24	3.9	195/130 to 230/150
4*	36	176	114	+32	-12	84	+18	4.8	190/120 to 260/150
5*	35	182	107	+20	+ 7	84	+31	5.4	170/130 to 230/145
6*	32	160	108	+30.	- 8	84	+24	5.4	185/110 to 238/140
7	38	222	140	+10	-20	78	+12	6.2	180/140 to 250/165
8	46	190	118	+38	- 8	78	+12	6.3	190/120 to 230/130
9*	35	210	140	+70	-10	90	+24	7.5	200/130 to 250/170
10*	42	158	112	+42	- 8	84	+36	8.7	160/115 to 240/160

 $^{^{\}circ}$ Heat tent at 40 to 60 $^{\circ}$ C. was placed over trunk forty-five to ninety minutes before injection of epinephrine was given. Tent was allowed to remain in position throughout the experiment.

relation between the systolic and diastolic pressure changes and the magnitude of the decrease in the surface temperature of the digits.

Although there was no correlation between the rate of injection of epinephrine and the blood pressure changes in the two groups as a whole, in individual instances the systolic pressure followed the rate so closely that it could be controlled fairly accurately by modifying the rate of injection. It is probable that much higher rates of injection would result in collapse, with a corresponding fall in the systolic blood pressure. Blanching of the face proved to be a reliable sign of the onset of the epinephrine effect; the pallor persisted until the injection was discontinued, when it was succeeded by slight flushing of the face and neck.

It was observed that placing a heat tent (40 to 60° C.) over the trunk for forty-five to ninety minutes previous to the injection of epinephrine produced no appreciable fall in blood pressure, and that its presence during the injection did not influence appreciably the response of the blood pressure to epinephrine. There was no correlation between the blood pressure response to epinephrine and to the cold pressor test.

COMMENT

In showing that the systolic blood pressure of patients with essential hypertension is no more responsive to epinephrine than that of subjects whose blood pressure was normal, we have corroborated the results of previous investigators; ⁵⁻⁹ the fact that epinephrine, whether injected subcutaneously or intravenously, produces relatively little change in diastolic pressure has also been observed before. ¹³⁻¹⁶

Bauer,¹³ in 1912, attributed the rise in systolic pressure to increased cardiac activity, and the relatively slight rise, or decrease, in diastolic pressure to peripheral dilatation. The assumption that epinephrine produces vasodilatation in structures which contain a large proportion of the peripheral vascular bed is based on considerable experimental evidence. Vasodilatation occurs in the skeletal muscle of animals as a result of administration of epinephrine^{12, 17, 18} except when large doses are given.¹⁸⁻²⁰ Furthermore, vasodilatation occurs in the splanchnic area, provided that the general blood pressure is raised; this dilatation is partly reflex and partly passive.¹² However, in the skin the action is uniformly one of vasoconstriction.²¹

The complex nature of the factors which determine changes of blood pressure in man as a result of the administration of epinephrine, together with the impossibility, from a practical standpoint, of analyzing these factors separately, makes it impossible at the present time to give an absolutely reliable explanation of the action of epinephrine on blood pressure. Bauer's assumption of increased cardiac activity and peripheral vasodilatation is probably the most satisfactory. In some of our experiments peripheral vasodilatation was induced by heat before the administration of epinephrine in order to facilitate demonstration of the

vasoconstrictor effect, but usually this procedure did not lower the diastolic pressure appreciably, and therefore nothing was learned concerning the effect of peripheral vascular tone on the response of the blood pressure to epinephrine.

Inasmuch as elevation of the diastolic blood pressure is a characteristic feature of essential hypertension, the fact that epinephrine usually produces a considerable increase in systolic pressure and a relatively slight increase, or even a decrease, in diastolic pressure may be taken as evidence that essential hypertension is not due to the presence of increased amounts of epinephrine in the blood. Likewise, the comparatively slight influence of epinephrine on the diastolic pressure indicates that the response to the cold pressor test is not an epinephrine effect, for, when the cold stimulus applied in the test raises the systolic pressure to a considerable extent, the diastolic pressure usually also increases markedly.

It has long been known that epinephrine causes constriction of the capillaries and arterioles of the skin,²² and in our experiments, as well as those of Pickering and Kissin,⁹ it invariably produced facial pallor. However, the facial color of most patients with essential hypertension is either normal or somewhat red, which is incompatible with the hypothesis that this disease is due to hyperepinephrinemia unless one assumes that the cutaneous capillaries of these patients are resistant to the action of epinephrine.

CONCLUSIONS

A dilute solution of epinephrine (1:250,000) was injected at varying rates, over a period of fifteen minutes, into the anterior cubital veins of 12 persons whose blood pressure was normal and 10 patients with essential hypertension. The results were as follows:

- 1. The magnitude of the rise in systolic pressure was the same in the two groups. In the patients with hypertension the diastolic pressure decreased more frequently than in the subjects whose blood pressure was normal. In both groups the change in diastolic pressure was always relatively less than the change in systolic pressure.
- 2. The induction of peripheral vasodilatation by applying radiant heat over the trunk did not appreciably alter the response of the blood pressure to epinephrine.
- 3. There was no evident correlation between the effect of the cold pressor test and epinephrine on the blood pressure.

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THE STETHOGRAPH*

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METHODS for recording heart sounds have been worked out by many investigators. 1-8 It is possible to review here only some of the outstanding contributions.

Einthoven and Geluk⁹ (1894), using a stethoscope, carbon microphone, and capillary electrometer, were the first to make really satisfactory records. Later the string galvanometer was substituted for the capillary electrometer. Einthoven, Flohil and Battaerd¹⁰ published the results of their work with the carbon microphone and string galvanometer in 1907. They suspended the microphone from the ceiling by three fine wires properly weighted for stability and connected it to the stethoscope through one arm of a Y-tube. The size of the opening in the other arm of the Y-tube was adjusted to remove apex impact vibrations. Their records were satisfactory, but the apapratus was complicated and its use restricted to the laboratory.

Wiggers¹¹ and Dean realized that Otto Frank's segmented capsule,⁵ although fundamentally good in principle, had faults which seriously affected the quality of the sound records. They were primarily concerned with modifying the original Frank capsule so as to eliminate the low-pitched sounds caused by the "apex thrust." They also devised a capsule diaphragm with a sufficiently high natural period to record sounds of 100 to 150 cycles per second without distortion. Briefly, the Wiggers-Dean improvements of the Frank capsule consisted of (1) the use of a thinner and lighter membrane made of rubber cement, (2) the provision of a large side opening in the pickup tube to eliminate the low pitches of the apex thrust, and (3) the exclusion of extraneous noise by enclosing the capsule in a housing having a glass window. The method of Wiggers and Dean had an advantage over that of Einthoven in that it eliminated adventitious vibrations produced in the microphone.

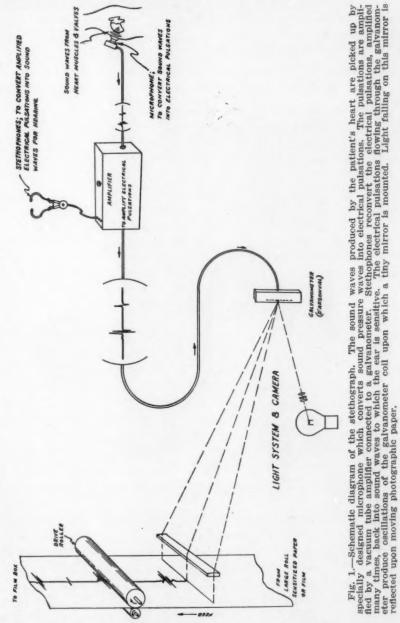
Williams and Dodge¹² found that these adventitious vibrations were due to undamped motion of the carbon particles in the microphone Einthoven used. In 1920 Williams adapted an electromagnetic telephone to convert sound vibrations into electrical impulses. Because of its low initial sensitivity this method required an amplifier to obtain the necessary over-all amplification.

The stethograph† designed by the writer and introduced as the electrostethograph¹³ is described in the following paragraphs. A schematic diagram of the instrument is shown in Fig. 1. It is made up of three main

^{*}Received for publication March 3, 1938.

[†]Manufactured by the Cambridge Instrument Company as the Cambridge Stethograph.

components, namely, a microphone, an amplifier, and a recorder, and is contained in a single case weighing 22 pounds complete (Fig. 2). It operates on 110 volt alternating current.



The microphone is of the crystal type, and therefore free of inherent noises. The special crystal element is contained in a carefully designed case which provides an airtight housing for the crystal, eliminating the effect of room noises. In addition, the shape of the interior is such that, when combined with the natural period of the crystal elements, resonance over a desirable frequency band is produced. Also, the necessary filtering (to be discussed later) is obtained acoustically in the microphone rather than electrically in the amplifier. The choice of the frequency band to be covered by the microphone was guided by the studies of Cabot and Dodge¹⁴ and Williams and Dodge.¹²

The microphone provides an amplification increase of 300 per cent to 400 per cent within this desirable band, viz., 75 to 550 cycles per second

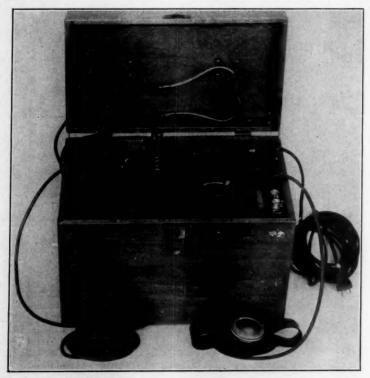


Fig. 2.—The Cambridge Stethograph (Courtesy of the Cambridge Instrument Co., New York).

(Fig. 3). The effects of room noises which are above this band are therefore greatly reduced. This accounts for the high "signal-to-noise ratio" obtained on the records. The effect is even more pronounced on the auditory senses because of the shape of the audibility curve of the human ear.^{15, 16} "At the lower and upper limits of audition it takes about a hundred million times as much energy to enable one to hear as it does in the range of 1000 to 5000 cycles where the ear is most sensitive." This characteristic of the human ear explains why the low-pitched murmur of mitral stenosis must become quite loud before it can be heard. It is sometimes easier to feel the apical thrill of mitral stenosis than it is to

hear the accompanying murmur because the sense of feeling is more acute than that of hearing in the portion of the frequency band occupied by this murmur.

A large amount of low-frequency energy is produced by the beating of the heart, most of which is caused by the striking of the apex against the anterior chest wall—the apex thrust. It is desirable to eliminate from the heart sound record all sounds which have no diagnostic importance. Those produced by the apex thrust are in this class, and the microphone was therefore designed to eliminate them. The cut-off and critical frequency points at the low-frequency end of the microphone response curve are important factors in the faithful recording of heart sounds, and the proper selection of these points determines the amount of diagnostic information furnished by the records.

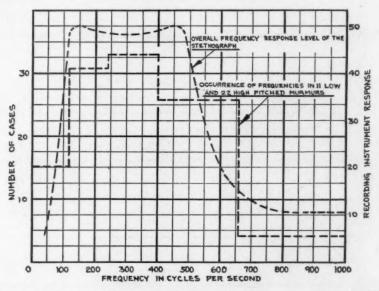


Fig. 3.—Comparison of the frequency band occupied by murmur sounds (as established by Williams and Dodge) with the response level of the stethograph.

The stethograph microphone is equipped with three bells which enable the operator to secure various degrees of filtering. The large open-faced bell shown with the microphone in Fig. 2 is called No. 1. The No. 2 bell is similar in size but is covered with a diaphragm. The No. 3 bell is approximately of the same size as that used on stethoscopes. The records shown in Fig. 4, all taken on the same patient, illustrate the effects of various degrees of filtering obtained by means of these bells. In record A there is a predominance of extremely low-pitched sounds, or "waviness," although at regular intervals greater excursions indicating the first and second heart sounds are evident. There are some high-pitched sounds within the systolic interval appearing as very small notches on the low-pitched ones. There is also a sound appearing regularly within

the systolic interval which, with the first and second sounds, simulates a gallop. There is another sound in the diastolic interval resembling a third heart sound. The predominance of the extremely low-pitched components in record A, however, makes it quite difficult to interpret.

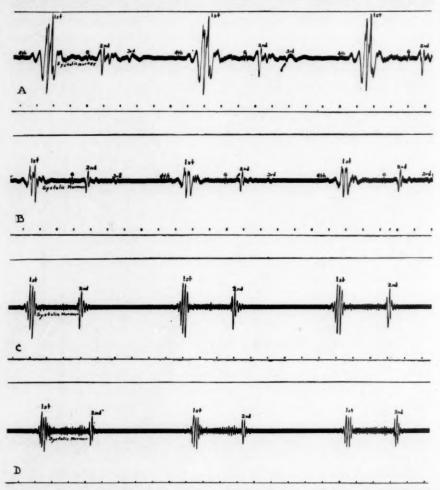


Fig. 4.—Effect of filtering heart sounds. The stethograph frequency response may be modified slightly by the use of three microphone bells supplied with the instrument. A, taken with a special microphone, using the No. 1 bell. Very little low frequency filtering is provided by this microphone. The base line is too "wavy."

B, taken with the standard microphone using the No. 1 bell. Base line is now straight.

 C_{r} taken with the standard microphone using the No. 2 bell. Some important sounds are filtered out.

D, taken with the standard microphone using the No. 3 bell. Systolic murmur is magnified.

Record B illustrates the effect of a slight amount of filtering. Just enough of the low-pitched component has been removed to straighten the base line to a fair degree. The presence of a systolic murmur, the systolic gallop, and the third heart sound is now quite evident. There is

also a sound about 0.15 sec. ahead of the first sound, the auricular, or fourth, heart sound. Record C was taken with more filtering. amplitude of the systolic murmur is increased in comparison with the first and second heart sounds. The base line is quite free from lowpitched components, but the systolic gallop, the third heart sound, and the auricular sound have disappeared. Record D shows the result of still more filtering. The systolic murmur has been artificially greatly increased in proportion to the first and second heart sounds, and, in the same manner, the low pitched sounds, as in the previous record, have been eliminated. On auscultation the systolic murmur was quite loud, but the systolic gallop, third heart sound, and auricular sounds were inaudible. The amount of low-pitched sound present in record A only impairs its diagnostic utility. Although the systolic murmur does not show so prominently in record B as it does in records C and D, other phenomena stand out more clearly. For these reasons the degree of filtering used in record B is more satisfactory from a clinical standpoint.

The second component of the stethograph is the amplifier. The frequency response of this unit is practically flat over the 50 to 1000 cycle band. Combining the microphone frequency characteristic with that of the amplifier gives the overall response curve shown in Fig. 3.

The third major part of the stethograph is the recorder. The chief requirements of a recorder for work of this kind are light weight, simplicity of construction, and stability. In addition to the need for accurate records, it is desirable that they be easy to interpret. This is facilitated by the choice of a proper base line width and by running the film at a suitable rate of speed. The optimum speed is dependent to a large extent upon the frequency of the sounds to be recorded. In the stethograph a speed of 75 mm. per second has been found to be most satisfactory.

In making records with the stethograph shown in Fig. 2, the microphone is placed over the patient's heart and the pulse pelotte on the wrist. The light beams from the galvanometer and pulse-recording mechanism fall upon a ground-glass screen as well as on the film, which makes it possible to view the heart sound vibrations and the pulse pressure variations while they are being recorded. The ability to see the sphygmogram while seeing and listening to the heart sounds is a valuable aid in timing certain murmurs and helps the physician to correlate his experience in auscultation with the sounds appearing on the record. Three stethophones (more by a special jack attachment) may be used at one time.

The value of the stethograph lies chiefly in greater accuracy of diagnosis and in the fact that it provides a permanent record which can be used to supplement or to replace the verbal or written description of auscultatory phenomena.

The recording of heart sounds has been accomplished, with varying degrees of success, by numerous investigators over a period of many years, but the method has not come into general use chiefly because the reliable apparatus available could not be taken to the bedside. With the introduction of the stethograph, which is a simple, accurate, and portable instrument, this difficulty has been overcome. It is to be expected that its use will aid in the solution of many of the problems of cardiac disease.

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HEART SOUNDS IN NORMAL CHILDREN*

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GRAPHIC records of heart sounds have been made by various techniques for over seventy years, but it is only recently that practical clinical methods have been devised. Lockhart's paper¹ should be consulted for a review of methods and for reasons why the stethographt which was employed in this study is the preferred instrument. It might be well to re-emphasize the fact that the value of the record obtained depends greatly upon the physical characteristics of the instrument used.

The stethograph records clearly vibrations below 600 cycles per second, but those of higher frequency are recorded in such low amplitude that they are difficult to read. The dominant frequencies of almost all heart sounds and murmurs are below 1000 cycles per second, and most of them do not exceed 600 cycles per second.^{2, 3} The high-pitched elements heard by the ear constitute but a small part of the vibrations actually present. In this instrument there is an amplification of 300 per cent in the range below 600 cycles per second, and therefore the murmurs which are hardest to hear, namely, the low-pitched apical diastolic murmurs, are the ones said to be most clearly recorded.

Schwarzchild and Feltenstein's instrument, although built on the same basic principles as the stethograph, is so designed as to introduce into the records approximately the same distortions which are produced in the human ear. The stethograph records the vibrations as they actually occur, rather than as they are heard.

Before beginning the study of heart sounds in children with rheumatic heart disease, it was necessary to establish standards for normal children, for only isolated reports of certain characteristics of heart sounds have appeared in the literature. Moreover, since the stethograph is just beginning to be generally used, an investigation of its range of applicability seemed desirable. So far, the only reports on the use of the stethograph are those of Martinez Cañas,^{5, 6} and he did not study a large series of normal records.

Through the courtesy of the Board of Education of Ossining, New York, and the kindness of Dr. Marshall Wood, the school physician, we were able to make records of 105 normal children in the Ossining public schools. Since these were taken at the time of the annual medical examinations, the physical status of each child was known. In addition, each

^{*}From Irvington House for Cardiac Children.

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[†]Manufactured by the Cambridge Instrument Company as the Cambridge Stethograph.

child was examined by the author, particularly with reference to cardiac size and auscultatory findings. A careful history was taken, with special attention to the possibility of rheumatic infection.

In making the stethographic records, the usual precautions were taken to eliminate extraneous sounds, such as room noises, breath sounds, and muscle sounds. However, since these records had to be made in the public school, a certain amount of noise was unavoidable. Whenever the extraneous noise was great enough to interfere with interpretation of the record, another tracing was made. Routinely, records were taken at the apex with the subject in the left lateral position, and also over the pulmonic and aortic areas with the subject in the sitting position and leaning forward slightly. It was found important to keep the children warm and comfortable in order to avoid extraneous noises due to muscle tension or shivering. The child was asked to take a deep breath, breathe out, and then to hold his breath in expiration while the record was made. Some of the children made such an effort not to breathe that muscle noise was introduced. With these the record was started in expiration and continued through one or two respiratory cycles. The microphone was held against the chest wall by means of a rubber strap. A microphone bell with an opening 2 inches in diameter was used. Even with this wide opening it was essential to have the bell in exactly the right position and applied as lightly as possible. It is well known how sharply diastolic murmurs are localized, and we have found this to be true of third heart sounds, also. The position of the microphone was checked by auscultation and by watching the vibrations on the screen of the machine. The same amplification was used in every instance.

TABLE I
DISTRIBUTION OF PATIENTS ACCORDING TO AGE AND SEX

AGE	5	6	7	8	9	10	11	12	13	14	15	16	17	TOTAL
Girls	4	3	4	3	4	4	5	6	1	1	1	-	-	36
Boys	2	6	2	4	2	4	2	11	10	12	4	6	4	69

RESULTS

Table I gives the sex and age distribution of the children whose heart sounds were recorded in this study. Neither age nor sex made any difference in the kind of records obtained.

Rhythm.—Sinus arrhythmia was present in all cases. The intersphygmic intervals were greater with normal respiration than when the breath was held, but always amounted to at least 0.03 sec. In 4 per cent of the cases the variation was so great as to amount to sinus arrest. No other arrhythmias were noted.

Heart Sounds.—Records of heart sounds are difficult to analyze, principally because heart sounds are never pure musical notes having single frequencies but are mixtures of frequencies, i.e., noises. Therefore, when the rate of vibration of heart sounds or murmurs is mentioned in this paper the dominant frequency is meant.

There are, of course, wide individual variations in these records. Certain patterns stand out as normal (Fig. 1). The first and second sounds are always prominent. The first sound consists typically of a few vibra-

tions of about 80 to 150 cycles per second preceded by two or three vibrations of increasing intensity and pitch and followed by several vibrations decreasing in pitch and intensity. The second sound starts more abruptly, is frequently shorter and somewhat lower in pitch (70 to 130 cycles per second) and of the same or less intensity. It, too, decreases in pitch and intensity toward the end. Schwarzchild and Feltenstein's findings agree roughly with these, the discrepancies being due to the different instruments used.

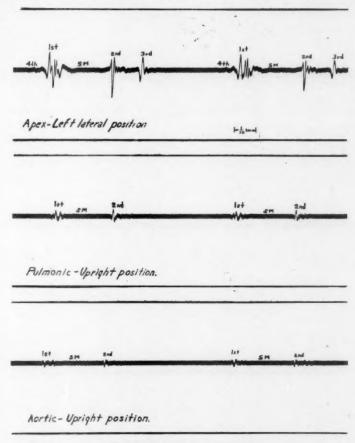


Fig. 1 .- Normal heart sounds.

Only a separation of the sound into two distinct components was interpreted as true splitting (Fig. 2). In 24 cases (23 per cent) a split first sound was noted. In 38 cases (36 per cent) the second sound was split, and in 15 (14 per cent) of these both sounds were split. Split first sounds were recorded most clearly at the apex in 23 instances, the division in the other case being most distinct in the aortic region. In 8 cases the splitting was also visible in either the pulmonic or aortic tracing or both. Split second sounds were always clearest at the pulmonic

area and often distinct at the apex (25 cases). Siemsen⁷ reports that in a group of normal boys ranging in age from 5 to 18 years split sounds were an almost constant finding. Cossio and Braun Menéndez,⁸ in a group of 25 normal children from 5 to 10 years old, found two cases (8 per cent) of reduplication of the first sound and 12 cases (48 per cent) of reduplication of the second. Some clinicians regard a split second sound as suggestive of mitral stenosis, but its high incidence in normal children disproves this idea.

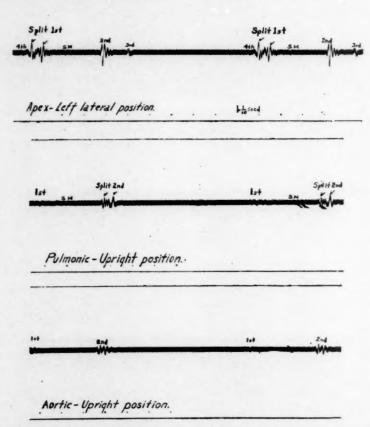


Fig. 2.—Normal heart sounds showing splitting of the first sound at the apex, and of the second at the base.

A third heart sound was audible in only 6 cases (6 per cent), but it appeared in the apex tracings of every child, being clearcut in 69 cases (66 per cent) and rudimentary in the rest. This third sound occurs from 0.11 to 0.15 sec. after the beginning of the second sound, always remaining at the same distance from the second sound in any single tracing. It is made up of one main vibration and sometimes one or more lesser vibrations of 20 to 50 cycles per second. The intensity of this

sound is quite variable; it is sometimes louder than the second (Fig. 3). Changes in rate occurring both during normal breathing and following exercise were studied carefully. Differences in cycle lengths were found to be due entirely to variations in the interval between the third sound and the following auricular sound (Fig. 4). The third heart sound is separated from the second by a constant interval which is not influenced by changes in heart rate due to exercise or respiration. Siemsen⁷ found that 2 per cent of his group of school boys had third heart sounds in the upright position. Thayer9 observed that the third heart sound is best heard when the patient lies on his left side. Braun Menéndez and Orias¹⁰ recorded third heart sounds in 60 per cent of 100 medical students; Pereira¹¹ found that 32 per cent of a group of 50 normal pregnant women had third heart sounds in their phonocardiograms; and Segura¹² noted no third heart sounds in the records of 120 normal infants, but all of these studies were made with apparatus which is less sensitive to low pitches than the stethograph, which fact may well account for the lower incidence. Other observers (Wolferth and Margolies, 13 Braun Menéndez and Orias, 10 and Duchosal 14) have noted that the physiologic third sound coincides with the final third of the V-wave of the phlebogram, that is, with the period of rapid filling of the ventricles. Some 15 think that it is caused by the opening of the mitral valve, and others10 that it is due to vibrations of the walls of the ventricles set up by the sudden impact of blood from the auricles. In any event, it must be a physiologic phenomenon, for it is recorded by the stethograph in every normal child.

In 94 per cent of this group of normal children, the first sound at the apex was preceded by an interval of 0.05 to 0.10 sec. by another sound consisting of one, sometimes two, vibrations of 25 to 60 cycles per second, and of low intensity. The interval between these two sounds is soundless, showing that this earlier sound is not a presystolic murmur. Braun Menéndez and Orias, 10 in their series of medical students, report 20 per cent as showing auricular sounds preceding the first. In Pereira's work¹¹ with pregnant women, he found an incidence of about 17 per cent. Segura¹² noted a clear or vestigial auricular sound in 69 per cent of normal infants. His description of the sound is similar to that reported in this paper. In cases of heart block it becomes possible to show that auricular contraction is accompanied by a group of sounds composed of two sets of vibrations separated by a short interval.6, 16, 17, 18 The second component, which occurs at the end of auricular systole, ordinarily forms the initial vibrations of the first sound, and is best transmitted to the precordium. The first component, which occurs at the height of auricular systole, is best transmitted to the esophagus. Both groups correspond in time to the early sound recorded in the stethograms of normal children. The interval between these two sounds of auricular origin does not correspond to the P-R interval; it may be the same, but

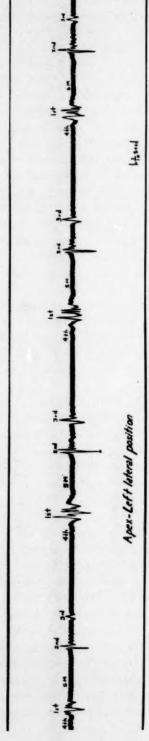


Fig. 3.-This record shows how respiration may alter the intensity of the various heart sounds.

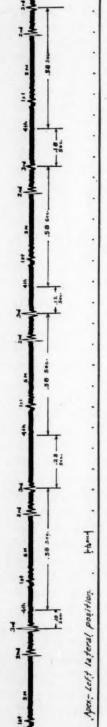


Fig. 4.—In this record, taken during respiration, the interval between the fourth, or auricular, sound and the succeeding third sound is constant (0.58 sec.), whereas the interval between the third and fourth sounds varies from 0.10 to 0.25 sec. The changes in the latter interval are due to shows are hypthmia.

it is usually less. In seven cases in which electrocardiograms and stethograms were made simultaneously, the interval between the "auricular" and first sounds was less than the P-R interval in four cases, equal to it in one case, and slightly greater in two cases. The first component, which is synchronous with the height of auricular systole, has been attributed to vibrations of the ventricular wall due to expulsion of blood from the auricular systole, ¹⁸ to vibrations of the auriculoventricular valves caused by auricular systole, ¹⁹ and to increased tension of the auricular wall and compression of blood in the auricular cavity. ¹⁶ The second component, which normally initiates the first sound, has been ascribed to ventricular distention, ¹⁰ to change of position of valve leaflets, ¹⁶ and to valvular distention. ¹⁹

Variations in sounds.—The dominant frequencies of the various sounds tend to remain the same in each individual, regardless of the cardiac rate or of the sites at which the microphone is placed. The pattern of each sound tends to remain constant in successive tracings over the same area in the same individual, but to vary with change in site. The absolute and relative intensities of the sounds change greatly when the microphone is moved from one place to another and when the heart rate changes. The intensities of all the sounds vary in direct proportion to the heart rate. That of the first may increase as much as 900 per cent, the second 500 per cent, the third 800 per cent, and the fourth 1200 per cent (Fig. 4).

Systolic Murmurs.—Auscultation with the stethoscope showed that five of the 105 children had moderately loud systolic murmurs at the apex. They had no history suggestive of rheumatic infection, and no other signs of organic heart disease. In the stethographic records apical systolic murmurs were present in 90 per cent, and in most of the others the base line was so wavy that a systolic murmur may well have been present. In only one was the base line straight enough to rule out the possibility of a murmur. These murmurs have a frequency of about 120 cycles per second and are often transmitted to the pulmonic area. They follow the first sound, reach their maximal intensity early in systole, and gradually fade out, ending anywhere between the middle of systole and the beginning of the second sound. Those which are audible are similar to the others in appearance except for greater intensity. Table II shows the incidence (to ordinary auscultation) of functional systolic murmurs in other groups of normal children. No diastolic murmurs were observed in our series of normal children either by auscultation or in the stethograms. Thayer suggests that the assumption of the left lateral position causes mitral insufficiency and accounts for the murmur. It is generally agreed that in children faint systolic murmurs at the apex are of questionable significance, 20-23, 9, 24 and our records indicate that such murmurs are not pathologic.

TABLE II INCIDENCE OF FUNCTIONAL SYSTOLIC MURMURS AS DISCOVERED BY ORDINARY AUSCULTATION

AUTHOR	FIRST DECADE		SECOND DECADE		
Lincoln20		8.3%			
Gibbes ²¹	11.0%	7.0	10.7%		
Thayer9	56.4%		35.7%		

SUMMARY AND CONCLUSIONS

In order to establish normal standards, stethographic records were made on 105 apparently healthy school children. Four distinct sounds invariably accompanied each heart beat, namely, the first, the second, the "physiologic" third, and a supposedly auricular sound which preceded the first. The last two were low in pitch and usually of little intensity, and therefore are generally inaudible. The first or second sounds, or both, are frequently split.

Sinus arrythmia was always present. The differences in the intersphygmic intervals depend upon the time elapsing between the third sound and the following auricular sound. The intensities of the various sounds depend upon where the microphone is placed, and vary greatly with changes in the cardiac rate.

At the apex, a moderately low-pitched, usually faint systolic murmur was present in all instances, which suggests that too much significance should not be attached to such murmurs when they are barely audible with the stethoscope. No diastolic murmurs were encountered.

This investigation indicates that splitting of the first or second heart sound and the presence of a third sound have no pathologic significance.

The author wishes to thank Dr. Arthur C. DeGraff for his helpful suggestions throughout the course of this investigation.

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HEART SOUNDS AND MURMURS IN CHILDREN WITH RHEUMATIC HEART DISEASE*

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THE need of an objective method of studying heart sounds has long been felt. Observers differ as to the presence and timing of murmurs, and even the same observer varies in his ability to detect certain kinds of murmurs and sounds. The characteristics of some endocardial murmurs seem to change, and some even disappear from time to time. In such cases a means of recording heart sounds and murmurs would obviously be of great value. For this purpose we have chosen the stethograph† because it is accurate and easy to operate. The details of its construction will be found in Lockhart's paper.

Normal standards were established by analyzing the stethograms of 105 apparently normal school children,² and this is a comparative study of 130 children with rheumatic heart disease. The subjects were 130 children between the ages of seven and sixteen years, all of whom had unequivocal histories of polyarthritis, chorea, or carditis of a rheumatic type. In each case the rheumatic infection was apparently quiescent at the time of admission. All but a few of the children remained at Irvington House from six to twelve months; records were made at intervals of approximately three months. As would be expected, some of the patients had recrudescences of rheumatic fever during their stay, and stethograms were made once or twice a week in nine of these cases. Altogether, more than 500 satisfactory records were obtained.

The technique was the same as that used in making the records on normal children; tracings were taken with the patient lying on his left side and the microphone over the apex, and from the aortic and pulmonic areas with the patient sitting up.²

RESULTS

Table I shows the distribution of these patients according to age, sex, and degree of cardiac damage as determined by clinical and roent-genologic examination.

^{*}From Irvington House for Cardiac Children.

Received for publication March 3, 1938.

[†]Manufactured by the Cambridge Instrument Company as the Cambridge stethograph.

TABLE I

DIAG.	AG. POSS. AND POT.		M I		M I (9s)		M I AND		I AND S		M I AND S	
AGE (YR.)	F	M	F	M	F	M	F	M	F	M	F	М
7	1		1					1				
8			2	3	2		6	2				
9	1 1	1	5	4		1	2	9		1		2
10	1	2	4		1		4	2		3		
11	1		2	3	1		5	4	3	1		
12	1	1	7	2	2		4	5	2	1		
13	3			1		1	4	1	2	1		1
14	1		1				4	2		1		
15					1		1	1		1		
16						-						1
	7	4	22	13	5	2	30	27	7	9		4

The records taken during the inactive phase of the disease will be described first. The criteria of the New York Heart Association³ form the basis for the classification of these patients.

Rhythm.—Sinus arrhythmia was always present, as in normal children and was of the same degree. The cycle lengths varied in each record by at least 0.03 sec.

Possible and Potential Heart Disease.—(E and F, Fig. 1.) These 11 patients had all had rheumatic fever. All had systolic murmurs at the apex on auscultation, but no cardiac enlargement clinically or roentgenologically, and thus fell into the group classified by the New York Heart Association as possible and potential cardiac subjects. In the stethographic records, the heart sounds were like those of normal children in respect to pitch, intensity, and duration. The systolic murmurs were similar to those found in normal records in regard to pitch and length but tended to be of about the same amplitude as the normal ones which can be heard with the stethoscope. One record showed, following the third sound, a few small vibrations whose frequency was about 80 cycles per second. No diastolic murmur was ever heard with the stethoscope in this case.

Mitral Insufficiency.—(Fig. 2.) The New York Heart Association criteria for this diagnosis are enlargement of the heart and a systolic murmur at the apex. The 35 children in this group presented roent-genologic evidence of slight or moderate cardiac enlargement, and all of them had an easily audible apical systolic murmur which was "blowing" in quality. Thirteen of them had, in addition, an inconstant, short, faint, early diastolic murmur localized at the apex. These patients were included in this group because the latter murmur was inconstant, and there was no evidence of left auricular enlargement. In five of the stethographic records the second sound at the pulmonic area was disproportionately intense, which corresponds to "accentuation" in ordinary auscultation. Otherwise the heart sounds were all similar in shape to those in the normal series, that is, they follow the first sound, reach

their maximal intensity early in systole, and fade out toward the end of systole. These murmurs are of about the same intensity as the normal ones but are higher in pitch, reaching 150 to 200 cycles per second. One child's records showed a crescendo murmur which was also crescendo to auscultation. Thirty patients (86 per cent) had diastolic murmurs which followed the third heart sound, gradually faded out within the first half of diastole when the patients were at rest, were of low intensity,

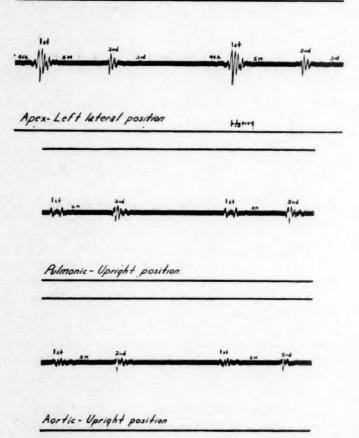


Fig. 1.—Heart sounds of a patient with potential and possible heart disease, having a history of rheumatic fever, and clinically showing a systolic murmur as the only possible evidence of cardiac damage. The record is like that of a normal heart.

and had a frequency of about 80 cycles per second. In ten of these thirty cases, records taken at different times showed sometimes a diastolic murmur and sometimes a third heart sound. The murmur even came and went with respiration (Fig. 3).

Mitral Insufficiency and Questionable Mitral Stenosis.—This group of six includes patients of two types: (1) those with cardiac enlargement, an apical systolic murmur, and a short, faint, early, apical diastolic murmur not rumbling in character, and (2) those with an apical systolic

murmur and a rumbling apical diastolic murmur, but without clinical or roentgenologic evidence of cardiac enlargement. Stethographic records in these cases showed systolic murmurs with the same characteristics as those of the preceding group. The diastolic murmurs were also like those of the preceding group except that one of them extended to the auricular sound.

Mitral Insufficiency and Stenosis.—(Fig. 4.) The criteria for this diagnosis, according to the New York Heart Association, are an apical systolic murmur, an apical diastolic murmur, and cardiac enlargement.

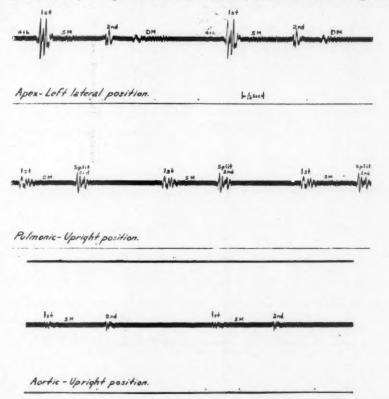


Fig. 2.—Heart sounds in mitral insufficiency. This patient gave a history of rheumatic fever and clinically showed cardiac enlargement, apical systolic murmur, and an inconstant early faint apical diastolic murmur.

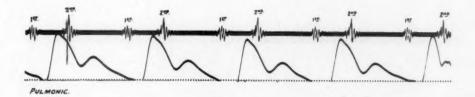
By these standards the patients said to have mitral insufficiency and questionable mitral stenosis and some of those said to have simply mitral insufficiency should be included here. However, in this group of 57 only those with an apical systolic murmur, an at least moderately loud, persistent apical diastolic murmur, and definite cardiac enlargement are included. In the stethographic records eight (14 per cent) showed greatly accentuated second sounds at the pulmonic area. The systolic murmurs were similar to those described before, but of greater intensity, six (10 per cent) being as loud as or louder than the first sound. There was great



Fig. 3.—Heart sounds in mitral insufficiency. This patient had a history of rheumatic fever and clinically showed cardiac enlargement, an apical systolic murmur, and an inconstant apical diastolic murmur. This record taken at cardiac apex during a respiratory cycle shows the variation possible during this time.

variability in the diastolic murmurs. Some were like those described above, but others were louder than the first and second sounds and lasted throughout diastole. The frequency of the vibrations varied greatly, but was mainly less than 120 cycles a second. Three of these loud, long diastolic murmurs showed a presystolic increase in intensity (Fig. 5). In twelve other cases (21 per cent) the interval between the auricular and first sounds was occupied by a few vibrations of about 100 cycles per second, of increasing intensity. This is apparently the presystolic murmur which is often considered of great importance in the diagnosis of mitral disease. It is to be remembered that these records were all taken with the patient at rest. Had the patients exercised immediately





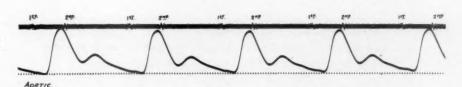


Fig. 4.—Heart sounds in well-established mitral stenosis and insufficiency. This patient had a history of rheumatic fever and clinically showed marked cardiac enlargement, a marked diastolic thrill at the apex, an apical systolic murmur, and a loud long rough apical diastolic murmur. Note the relatively quiet interval following the second sound.

before the records were made, it is possible the incidence of these murmurs would have been greater. In these records the characteristic murmur was a low-pitched sound beginning at the time of the third heart sound and continuing a variable time into diastole. There was always a relatively, though not absolutely, soundless interval between the second and third sounds.

Mitral Insufficiency and Stenosis and Aortic Insufficiency.—(Fig. 6.) The diagnostic criteria were the same as for the mitral lesions, plus a diastolic murmur at the base. There were sixteen patients in this group.

The stethographic records made from the cardiac apex were similar to those in the preceding group. Records taken with the microphone over the base of the heart show a diastolic murmur which begins immediately after the second sound, continues a variable distance into diastole, and is very low in intensity and comparatively high in pitch (180 to 240 cycles per second). Although these murmurs are easily audible with the stethoscope, they are difficult to distinguish in stethograms because of their low intensity. The reason for this difficulty lies in the fact

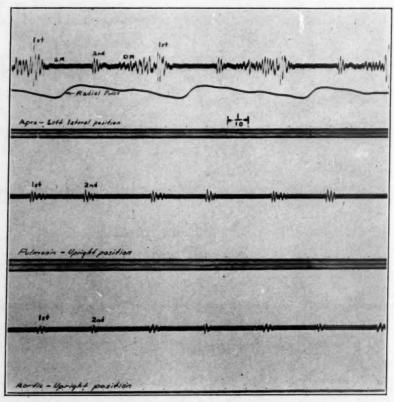


Fig. 5.—Heart sounds in mitral stenosis and insufficiency. This patient had a history of rheumatic fever and clinically showed moderate cardiac enlargement, a diastolic thrill at the apex, an apical systolic murmur, and a long loud rough diastolic murmur. Note the presystolic accentuation.

that of two sounds of the same intensity but of different pitch one will sound louder than the other to the human ear. A further discussion of this point will be found in Lockhart's paper.¹

Mitral Insufficiency and Stenosis and Aortic Insufficiency and Stenosis.

—In this group of four patients the diagnostic criteria were the same as for double mitral lesions, plus a diastolic blow and a rough systolic murmur at the base. The records were like those in the preceding group, with an additional systolic murmur at the base which was composed of a

mixture of frequencies, the most prominent being about 80 cycles per second. These murmurs begin immediately following the first sound and last throughout systole.

Active Carditis.—(Fig. 7.) Stethographic records in nine cases during periods of rheumatic activity were made at weekly or semiweekly intervals. When there was clinical evidence of carditis, sinus arrhythmia was less marked, and in three cases (33 per cent) was absent in at least two records.

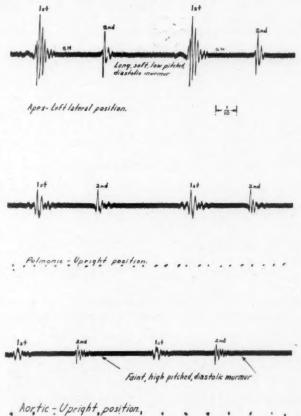


Fig. 6.—Heart sounds in mitral insufficiency and stenosis and aortic insufficiency. This patient had a history of rheumatism and clinically showed cardiac enlargement, apical systolic and diastolic murmurs, and a diastolic blow at the base.

This may be explained largely by the fast heart rate which accompanies carditis. However, the rate in stethograms showing absolutely regular rhythm was somewhat slower than that in several records in which sinus arrhythmia was present. Periods previously silent are no longer so for several reasons. It was noted in the tracings of normal children that changes in cardiac rate affected only the time interval between the third and auricular sounds. The tachycardia associated with rheumatic activity is similarly at the expense of the quiet part of diastole. There

is also an increase in the length and intensity of murmurs already present. Moreover, new murmurs often appear at this time. The murmurs which appear in these records do not differ from those seen when the rheumatic process is inactive. Clinically, the heart sounds are said to be of "poor" or "valvular" quality, but this difference does not stand out in stethograms. However, in three (33 per cent) the first sound decreased in amplitude, though remaining within the range of normal. This change takes place in the low-pitched components. The sounds are as long as normal ones. When a diastolic murmur of moderate intensity appears, the third sound is frequently lost. If the murmur disappears

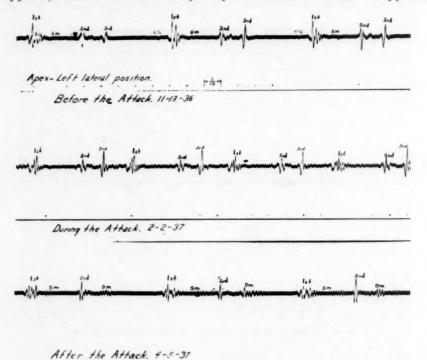


Fig. 7.—These records were taken at the cardiac apex of the same patient. The first was taken before, the second during, and the third following an attack of rheumatic fever. At the time of the second record the patient was considered to have gallop rhythm.

or becomes much fainter with recovery, the third sound reappears. During frank rheumatic activity the fourth sound was increased in amplitude, though still well within normal limits, in two cases (22 per cent). Gallop rhythm was noted with the stethoscope in three cases. The stethograms of these patients (Fig. 7) at this time showed a prominent third heart sound, although its intensity was not greater than in normal children. There was also a first sound of somewhat less than average intensity, but still well within normal limits. These sounds probably represent the gallop rhythm heard with the stethoscope.⁴

The small number of cases of active carditis included in this study, and the lack of consistency in the appearance of the stethograms preclude any statement as to the value of such records in the diagnosis of active carditis. However, a definite change in the appearance of the record might suggest the presence of carditis.

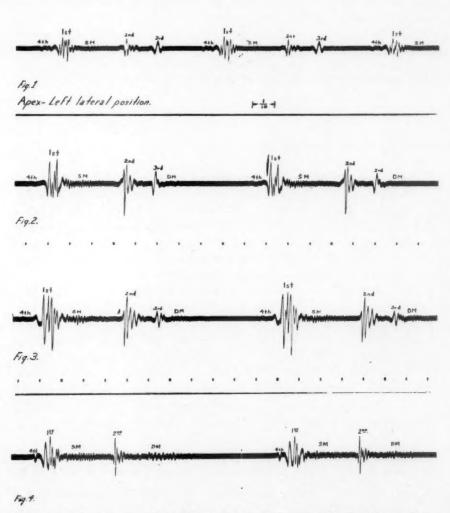


Fig. 8.—This series of records taken at the cardiac apex of four patients shows gradations between a third heart sound and a rrank diastolic murmur.

DISCUSSION AND CONCLUSIONS

Stethograms of children with quiescent rheumatic heart disease show the same degree of sinus arrhythmia as those of normal children. In carditis this arrhythmia may disappear. Gallop rhythm may be due, at least in some cases, to tachycardia, accentuation of the third heart sound, and lessening of the intensity of the first heart sound.

Nineteen per cent of 119 children with organic heart disease had abnormally loud second sounds at the pulmonic area. Otherwise the heart sounds were not outside the normal range.

The apical systolic murmurs which were present in cases of mild cardiac damage appeared similar to those found in normal records except for increased intensity. With more advanced heart disease these murmurs became slightly higher pitched.

The differences in the apical diastolic murmurs were interesting. On the whole, as would be expected, the louder, longer murmurs occur in cases in which the heart disease is relatively severe. However, when the disease is not so far advanced the short, early, faint diastolic murmur may come and go from time to time during periods of apparent inac-Stethograms of these children show sometimes tivity of the disease. a murmur and sometimes a third heart sound. The murmur may even come and go with respiration. Moreover, there are all gradations from a simple clear-cut third heart sound, such as is present in the stethogram of every normal child, to an obvious long diastolic rumble (Fig. 8). It is evident that there are adequate objective grounds in such cases for the disagreement of different observers concerning the presence of a diastolic murmur. This last series of records brings up the question of what should be called a murmur and what only a sound. In this work we have arbitrarily used the term murmur to designate any series of waves composed of more than three vibrations.

The significance of inconstant, faint, early diastolic murmurs has been widely debated.5, 6, 7 It is possible that they may be due to slight relative stenosis of the mitral valve caused by cardiectasis without enlargement of the mitral orifice. Do such murmurs ultimately disappear, or are they the earliest sign of mitral stenosis? If stethographic records can be made in such cases at intervals over a period of years this question may be answered.

The author wishes to thank Dr. Arthur C. DeGraff for his helpful suggestions throughout the course of this investigation.

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Special Article

FIRST INTERNATIONAL HEALTH BROADCAST

7:30-8:00 P.M., MAY 2, 1938

Opening Announcement (Haddon Hall, Hotel, Atlantic City):

This evening the National Broadcasting Company brings you the First International Health Broadcast. This program, conceived by a committee of Irvington House, Sanatorium for Children with Rheumatic Heart Disease, and presented under the auspices of the American Heart Association, is designed to stimulate greater public interest and action in one of the major child health problems—that of heart disease. The speakers on this evening's program, who will be heard from London, San Francisco, and Atlantic City, will be introduced by Dr. Howard W. Haggard, Professor of Applied Physiology at Yale University.

Dr. Howard W. Haggard, Commentator:

You are about to take part in an event unique in radio broadcasting. This is a pioneer venture—the first international medical consultation on a topic of grave significance to every man, woman, and child.

There are a few fortunate individuals who, in matters of health, may obtain the aid of famous physicians, but none could ever have such a consultation as is presented for you in your home tonight. This broadcast brings together men of pre-eminent authority from cities as distant as San Francisco, Boston, New York, and London. Representing on this occasion the medical profession of Great Britain is Lord Horder, the Physician-in-Ordinary to His Majesty King George VI.

The subject upon which these physicians will speak is "Heart Disease in Children." Its importance to you lies in the fact that today heart disease—a consequence of rheumatic fever—takes a greater toll of health and life, and destroys more children of school age, than any other ailment.

The discoveries of medical research, the efforts of our physicians, the enlightenment of our public, have worked together to free us from many of the once major mortalities of early life. We have seen the "choleras" of infancy wiped out and the diphtheria of childhood; we have seen the tuberculosis of adolescence brought under control. But the crippling rheumatic fever has not yet yielded, and it will not yield except before a united effort—the concerted determination to rid ourselves of it.

Tonight great medical authorities will define for you the situation that confronts us; they will tell what has been done and what can be done. Their words will be a call for you to enlist in a warfare of humanitarianism, a warfare against a disease that knows no national boundaries.

This call for your support to protect our children—and their children—by ending this disease is sponsored by the American Heart Association of New York City. This first international health broadcast was arranged by its Committee on Radio Publicity headed by Dr. Arthur C. De Graff, who is medical director of Irvington House, sanatorium for the care of children suffering with heart disease.

It is my great privilege now to present to you as the first speaker, Lord Horder, President of the Medical Society of London, Chairman of the Empire Rheumatism Council, and Physician-in-Ordinary to the King of England.

Lord Thomas Jeeves Horder:

Greetings to America, sturdy warrior in all campaigns against disease, the real enemy of humanity. The world's greatest monument to the triumphs of medical research is the Panama Canal, which your engineers were able to build only by first abolishing tropical disease in this area. May you do as good work against rheumatic disease, which is today Public Danger No. 1 of civilized mankind.

In our country rheumatic disease is the greatest of the killers, though it conceals its murders under the mask of heart disease. On the evidence of trustworthy statistics, we find that it is as it is with you: Organic disease of the heart is chiefly rheumatic in origin, and organic heart disease is the cause of over one-third of our annual death rate. One does not need to be a doctor to know of the number of heart cripples that are strewn throughout the community as the result of rheumatic inflammation during childhood.

How are we to grapple with this enemy? First by research to discover the causative factors. Then by diligent efforts in the field of preventive medicine to build up effective barriers against the operation of those factors. By such methods medical science has won splendid results in combating other scourges of man—bubonic plague, malaria, and typhus fever. I am confident it can be as successful with rheumatic heart disease.

Research to determine definitely the causes of rheumatism is the first essential. The prevention of disease is the ideal of modern medical science, and measures of prevention must be based on precise knowledge of causes.

This task of research into causes of rheumatic disease is a vast undertaking. It must, to quote a famous philosopher, "take all knowledge

for its province." It must investigate methodically, patiently, and with all precaution against mistake, every possible factor in causation. It cannot afford to base its policy on any single preconceived idea to the neglect of other fields of exploration.

We have much evidence here, as you have in America, that the type of rheumatism which affects the heart is closely associated with bacterial infection. It will surely not be long before we clarify this association.

But there must not be ignored what I shall call the sociologic factors, the influence of environment and possibly, also, of heredity. I have recently had the opportunity to study the figures of the incidence of acute rheumatic disease among a group of 30,000 youths, gathered into certain training institutions. All of them had been carefully examined and passed as first-class lives within the previous twelve months. Much the greater proportion of this group of youths were drawn from the poorer classes of the community. The incidence of acute rheumatism among them in a year was nearly five per thousand, and of other forms of rheumatism over seven per thousand. Of the sufferers, two died and seventy were permanently invalided. But in the much smaller proportion of this group of youths, drawn from the well-to-do classes, the cases of acute rheumatism and of other forms of rheumatism were so infrequent as to be almost negligible. From the same figures it could be seen that there was a similar relative incidence of such allied diseases as tonsillitis and acute ear trouble among youths drawn from different classes of the community. There is a clear hint, here, of a sociologic factor in the causation of rheumatic disease. Accepting, as I say I think we may accept, the fact that acute rheumatism is an infectious disease, the suggestion comes that some circumstances of early environment make the child's body a more favorable soil in which that infection can flourish.

But suggestions are not certainties. We must have certainty and, in the quest of certainty, we must follow up all the clues that offer themselves. So our investigations must be not only at the bedside of the patient and at the benches of the laboratory; they must explore conditions of climate, of diet, of housing, of occupation, to arrive at final conclusions.

The British Empire Rheumatism Council, of which I am chairman, has entered upon the task of exploring this wide field in the search for the causative factors of rheumatic disease generally. We shall have a complete clinical and research unit working specially on this problem of rheumatic heart disease. The Council will work in cooperation with your scientists and those of other nations. In particular it welcomes the prospect of having a close alliance in its work with the United States. Your people have won world-wide renown for the great measure of scientific skill and of philanthropic support which you have brought

to the effort of winning for man the fullest possible span of life and of a life healthy, vigorous and free from disablement. Rheumatic diseases are responsible, in our community, and probably also in your community, for one-sixth of the total illness; they cause more suffering and more death than cancer and tuberculosis combined; and they are notably cruel in their attacks on youth, wrecking life at its threshold.

A splendid vision can engage the minds of men if they will be wise enough to see the futility of fratricidal strife and recognize that their true enemies are the forces of disease—the vision of a world from which all preventable illness has been banished; in which sickness will come only as the penalty of wickedness or of folly. It is that vision which engages our attention just as it is engaging yours.

Dr. Howard W. Haggard, Commentator:

You have just heard Lord Horder of England, the opening speaker in this, the first international health broadcast which is sponsored by the American Heart Association. We turn now from London to San Francisco. The next speaker is Dr. William J. Kerr, President of the American Heart Association and newly elected President of the American College of Physicians. Dr. Kerr will explain the situation which confronts us from rheumatic heart disease in the United States.

Dr. William J. Kerr:

Lord Horder, we salute you from America. Our interests are happily joined upon this occasion. The American Heart Association is pleased to cooperate with the medical profession of Great Britain for this international broadcast so that the people in our respective countries may know the serious nature of one of our most crippling maladies—rheumatic heart disease.

Ladies and gentlemen of the radio audience, this disease is worthy of comment because it is related directly to the public health. It attacks children and young adults especially, and begins usually with symptoms and signs characteristic of rheumatic fever, generally known to the layman as inflammatory rheumatism. The damaging and more lasting effects are manifested in the heart. The blow comes when the individual is in the prime of life. The disability is usually progressive, and many of its victims die prematurely.

Let us consider the case of the child who suffers from rheumatic fever. After the stage of fever and painful joints and other less annoying complaints is passed, there is often a lull of months or years before there is a recurrence or the onset of complaints related to trouble in the heart. If the heart is seriously crippled, the capacity to do ordinary physical work is limited. The muscle fails and shortness of breath and swelling of the feet occur.

The loss of time and income in early and middle adult life because of this type of heart disease is greater than for any other chronic disease. According to the statistics of the United States Public Health Service, more than half of the deaths due to heart disease occur before individuals have lived out the normal span of life. Rheumatic heart disease alone causes at least 40,000 deaths every year, and the average age at which its victims die is 30 years.

Studies made in San Francisco have disclosed the fact that 20 per cent of workers on relief have shown some evidence of disease of the heart or circulatory system. Many of these workers had rheumatic heart disease. This is a greater incidence of such diseases than is to be found in the general population; presumably many of these workers, with their families, were on relief because of their physical incapacity. If these crippling diseases could be prevented, untold suffering would be avoided, and the benefits to individuals and their families and to the country would be enormous.

The American Heart Association has recognized the medical and economic importance of rheumatic heart disease. In many clinics and laboratories, studies are being undertaken to learn the facts about this disease, as you have heard from the other speakers. Already many promising beginnings have been made which we hope will be fruitful. It is now well recognized that the guilty offender, rheumatic fever, operates chiefly in temperate climates, generally during the late winter months, and chooses as victims chiefly children and adults who are poorly nourished. Even the well-to-do are not safe, but among them the incidence is very low. The disease occurs also, but less frequently, in our southern and southwestern states. Whether rheumatic fever is caused by some particular dietary deficiency, by an infectious agent, or by some combination of these with other factors is difficult at the moment to assert.

The American Heart Association is in a position to suggest how funds may be usefully employed to undertake studies which appear to offer some solution for our problems. In many centers laboratories are equipped to work independently or in cooperation with others on some phase of the problem. To date little support has been given to research projects in this field. The situation is not a hopeless one. New avenues of approach are being constantly opened, and methods of treatment have greatly improved the lot of the patient with heart disease. He can be taught to live within the capacity of his heart by curtailing his physical activity. The child with a damaged heart can be taught a sedentary occupation. When symptoms arise he can be given support by drugs and other means which will make his heart beat stronger. With the effective methods now known and in the hands of the intelligent physician, much good can be accomplished.

Dr. Howard W. Haggard, Commentator:

Dr. Kerr has defined the present status of one of our most serious maladies—rheumatic heart disease.

Control of this disease can come only from knowledge gained by medical research. At present such research is pitifully inadequately supported; it can become effective only when it receives the full aid of our public—a public informed and therefore aroused to pressing needs.

Dr. Homer F. Swift, of the Rockefeller Institute of New York City, will tell what is known of the cause of rheumatic heart disease.

Dr. Homer F. Swift (Certain Causative Factors in Rheumatic Heart Disease):

Rheumatic fever is apparently an infectious disease in which at least two causative elements must be considered: first, the hypothetical agent that induces the infection; and, second, the conditions which appear most favorable or unfavorable for the infectious agent to act.

Even though the nature of the causative agent is not definitely established, the conditions under which the disease appears and thrives can often be fairly well defined, and from this knowledge much can be done to impede its progress. We shall, therefore, consider mainly the so-called predisposing factors.

Rheumatic fever occurs chiefly in childhood, adolescence, and early maturity. In some instances the heart is unaffected, in others only temporarily involved, but in many it is permanently damaged, so that even if the infection be fully overcome, there are scars in the heart valves and muscle which interfere with the proper functioning of the organ. Cardiac involvement occurs most frequently in the rheumatic fever of childhood, and with each subsequent decade of life there is a steadily diminishing tendency for rheumatic fever to occur, and a diminishing liability for the heart to be attacked, even if a person contract the disease. This relationship between age and susceptibility or resistance is an important feature of the malady.

A second peculiarity is the tendency for the disease to recur in the same person. Apparently tissues, once involved, become favorable ground in which the infectious agent can work, and this is one of the serious aspects of rheumatism of the heart. One or two attacks may be well tolerated but, when they are numerous, more and more damage occurs until finally the heart is unable to respond to even slight extra bodily exertion.

While rheumatic heart disease occurs in people in all economic conditions, it is much more frequent among the poor, where crowding, undernutrition, and bad hygienic surroundings prevail. Moreover, there is often a tendency for several members of a family to have the disease.

Whether this is the result of the passage of a specific contagious element directly from one person to another, or is due to an hereditary vulnerability of certain people's tissues is, as yet, unsettled.

Climatic factors seem very important. Along the Atlantic seaboard and over continental North America, most cases occur in the spring. With the onset of warm weather rheumatic fever is more infrequent, and patients suffering from the disease tend to recover. In more southern climates the incidence is less, and the attacks are usually mild. Moreover rheumatic heart disease rarely occurs among inhabitants of the tropics, unless they have contracted it elsewhere.

More extensive studies of these climatic factors are needed, but the relatively lower incidence of rheumatic fever both during the northern summer and in the tropics is noteworthy; and this information may be used in attempting preventive treatment when it is economically possible to have a patient with rheumatic heart disease live in a favorable climatic environment for a long time. Unfortunately, because of financial difficulties, most sufferers from this disease are unable to make this move; and no sanatoria in especially favorable climatic situations, comparable to those that exist for tuberculosis patients, have been provided either by private endowments or public health authorities. By and large, there is a surprising lack of institutional facilities for the adequate care of rheumatic patients over long periods.

Certain infections are at times so closely connected with rheumatic fever and active rheumatic heart disease that their causative relationship must be seriously considered. These are streptococcal infections such as tonsillitis, sore throats, acute sinusitis, and middle ear disease, which are often forerunners of rheumatic fever as well as serious complications in a patient with active rheumatic disease. It is true that people suffer these respiratory diseases without developing rheumatic fever, but a person who has had rheumatic fever is in danger of a relapse or new attack if he contracts such a streptococcal infection. Even though this course of events does not definitely establish a causative relationship, the peculiar sequence suggests that these particular infections of the respiratory tract are very important in the life of a rheumatic subject.

While it has been possible to mention briefly only some of the indirect causative factors of rheumatic fever and rheumatic heart disease, attention to the various problems suggested will doubtless be important in the campaign which must be waged against this very crippling affliction.

Dr. Howard W. Haggard, Commentator:

Dr. Swift of the Rockefeller Institute has spoken on our present knowledge of rheumatic heart disease. Cure and prevention must await further medical research. But in the meantime there are thousands already crippled by the disease; many thousands more may be injured before it is exterminated. With good medical care these cripples can be helped toward full and useful lives. Vital as is their need, there are in the United States few institutions devoted to the care of children with heart disease.

The next speaker in this international broadcast is Dr. T. Duckett Jones, of Boston, from the House of the Good Samaritan.

Dr. T. Duckett Jones (Treatment of Rheumatic Heart Disease in Children):

Since rheumatic heart disease is the result of rheumatic fever—itself a generalized disease with signs and symptoms often remote from the heart—both must be considered with regard to treatment.

At the beginning, the patient is usually quite ill and uncomfortable. Such patients are best treated in hospitals where good medical and nursing care are available. This is especially true of heart failure, which is not uncommon. As the acute phase of the disease subsides, the problem becomes one of prolonged bed care—rheumatic fever is a chronic disease persisting for months, and at times, several years. Especially during the first five or six years after the attack, the patient is prone to develop recurrences. These attacks are often preceded by sore throats or colds.

At the present time, this prolonged bed care may be satisfactorily obtained in only a few institutions. There is a great need for convalescent homes or hospitals where a long period of convalescence may be provided for cardiac patients. Despite the lack of statistics proving the value of such long bed rest, some of the obvious advantages may be mentioned:

- (1) Following the acute illness, mild symptoms may continue for long periods.
- (2) Even after the disappearance of the clinical, or obvious, symptoms, laboratory tests usually show a continuation of the activity of rheumatic fever.
- (3) Rheumatic heart disease may develop or increase as long as active rheumatic fever continues.
- (4) As long as there is even laboratory evidence of active rheumatic fever, recurring attacks are frequent.
- (5) Continued rest in bed allows the body to conserve its entire energy for the fight against disease. It decreases the exposure to such infections as often cause an increase in rheumatic fever symptoms (most frequently colds and sore throats).
- (6) Coincidentally with bed rest in the proper environment, the patient should be freed from varied anxieties, emotional or family difficulties.

- (7) Such general recovery measures as proper food and ultraviolet light treatment are easily available.
- (8) The education of the patient and family concerning the problem of rheumatic fever and rheumatic heart disease is an important consideration.
- (9) A good psychological attitude on the part of the patient toward his disease can best be attained during such periods of long rest.
- (10) The patient may be given bedside instruction, and his regular scholastic standing maintained.
- (11) Vocational guidance and occupational handierafts, important in such a disease, may be provided.

Following the cessation of active rheumatic fever, convalescent care may give abundant help during the period of gradual rehabilitation, prior to the return home and to a community life consistent with the existing degree of rheumatic heart disease. With the return to some semblance of normal life, frequent visits to the family or clinic physician are advisable. At this time the physician should be on the alert for evidence of renewed activity of rheumatic fever. He should advise the patient of the measures that may be helpful in keeping his general health and resistance at a high level. Some of the measures to be considered are rest periods, a well-balanced diet with suitable vitamins, the avoidance of fatigue and of sore throats and colds, the restriction of physical activity in some patients, and the betterment of home conditions.

The patient with moderate to severe rheumatic heart disease should be advised as to the degree of his physical activity. He should be educated to live within the limits of his heart reserve and trained for sedentary occupations when necessary. The use of drugs at times helps considerably to increase the efficiency of the heart.

There are no sure, rapid cures for rheumatic fever or rheumatic heart disease. Long care is essential. In some instances, the removal of tonsils, abscessed teeth, and other sources of infection is helpful, but will not cure the disease. Such procedures at the wrong time may even result in recurrences.

There are encouraging features. Of one thousand young patients given prolonged care and careful observation, 75 per cent are alive. The majority of them lead active, physical lives ten years after the onset of their disease. Six hundred of the thousand have no necessary restrictions of their activity, although nearly half of these have a slight degree of rheumatic heart disease. In only 150 are there moderate to severe restrictions of their lives due to rheumatic heart disease.

Further studies and varied laboratory investigations are needed. The combined interest of the medical profession and the public should result in the solution of many of the problems of rheumatic fever and rheumatic heart disease.

Dr. Howard W. Haggard, Commentator:

Ladies and gentlemen, you have heard the four speakers on the first international health broadcast: Lord Horder, of London; Dr. Kerr, of San Francisco; Dr. Swift, of New York; and Dr. Jones, of Boston. They have defined for you one of the major medical problems of today—the problem of rheumatic heart disease. In enlisting your aid these physicians have presented only bare facts. But behind those facts, treated with such restraint, lie the thousands and hundreds of thousands of heart-breaking scenes—the parents, the homes, the stricken children—each is a tragedy of life lost or life blighted by a disease which we must eradicate.

There must be medical research; there must be adequate care. There will be when you are determined that there shall be. It is public opinion shaped by sound information—information such as you have heard this evening—which determines what will be done.

For those who wish more information on rheumatic heart disease a special pamphlet has been prepared by the American Heart Association, New York City. It will be sent upon receipt of 5 cents in postage.

And now, ladies and gentlemen, we bring to a close the first international health broadcast—a pioneer venture.

Closing Announcement:

This evening the National Broadcasting Company has brought you The First International Health Broadcast, conceived by Irvington House, a Sanatorium for Children with Rheumatic Heart Disease, and sponsored by the American Heart Association. The speakers heard during this program, defining the major medical problem of rheumatic heart disease, were Lord Horder, of London; Dr. Kerr, of San Francisco; Dr. Swift, of New York; and Dr. Jones, of Boston. They were introduced by Dr. Howard W. Haggard, Professor of Applied Physiology at Yale University.

For those who wish more information on rheumatic heart disease a special pamphlet has been prepared by the American Heart Association and will be sent upon receipt of 5 cents in postage. Address your request to the American Heart Association, 50 West 50th Street, New York.

Department of Clinical Reports

ADAMS-STOKES SYNDROME INDUCED BY TRANSIENT, RECURRENT VENTRICULAR FIBRILLATION*

CASE REPORT

LOUIS H. SIGLER, M.D. BROOKLYN, N. Y.

THERE are comparatively few cases of ventricular fibrillation in man recorded in the literature. I have been able to find reports of only 24 individual cases, together with 22 additional cases recorded by Turner, Hanson, Kahn and Goldstein, Robinson, Dieuaide and Davidson, and Sigler, Stein and Nash in which electrocardiographic studies of the dying human heart revealed ventricular fibrillation as a transient phenomenon. In some of the reported cases the electrocardiographic evidence is not convincing.

One reason for the scarcity of reports is that ventricular fibrillation is usually fatal. The longest attack with recovery was six minutes in a case reported by Schwartz and Jezer. Another reason is that the disorder cannot be recognized clinically, and, unless electrocardiographic studies are made at death or in all cases of the Adams-Stokes syndrome, it may be missed.

The following case is reported because of the scarcity of such reports and because it offers additional information on the nature of the disorder.

CASE REPORT

L. F., a man 58 years of age, consulted me March 7, 1936, because of weakness, dyspnea, and retrosternal pain occurring on exertion. The symptoms followed an attack of "the grippe" three weeks previously. His family and past histories were essentially negative. He had been married thirty years and had never had any children. He had had no serious illness or venereal disease. His habits were good, but he always worried about the most trivial matters.

The physical examination showed a somewhat undernourished man whose height was 68 inches and weight 142 pounds. He had no pallor or cyanosis. There was slight enophthalmos; the pupillary reactions were normal to light and in accommodation. The gums were the seat of pyorrhea, and the pharynx was chronically inflamed. There was moderate peripheral arteriosclerosis and the blood pressure was 150/70. The dorsal spine was moderately kyphotic and the chest somewhat barrelshaped, with considerable depression at the lower end of the sternum.

The heart was slightly enlarged to the left, and the aortic arch was widened and tortuous. The heart rate varied between 33 and 70 per minute; the beating was regular except for frequent ventricular extrasystoles. The first and second sounds

^{*}Received for publication Jan. 16, 1938.

were accentuated at the apex but diminished at the base. There was a short, rough systolic murmur which was loudest at the apex and was transmitted to the anterior axillary line, to the left sternal border, and across the base.

Examination of the lungs showed some prolongation of expiration over both upper lobes anteriorly, and an occasional moist râle at the bases posteriorly. The abdomen was negative except for a bilateral inguinal hernia. The patient was moderately sensitive to pain, and stimulation of his carotid sinus elicited a moderate cardio-inhibitory response.

The clinical diagnosis was general arteriosclerosis, coronary sclerosis, atherosclerosis with some calcific infiltration of the aorta; slight left ventricular enlargement; myocardial fibrosis; partial auriculoventricular block and the anginal syndrome; emphysema; and bilateral inguinal hernia.

I saw the patient on many occasions thereafter; he seemed to improve symptomatically when his activities were restricted. Objectively, however, there was a gradual diminution in the intensity of the first sound, which seemed to split into two sounds when the heart rate slowed. His systolic blood pressure varied between 120 and 150, and his diastolic between 70 and 90.

On Nov. 11, 1936, he was found in the bathroom unconscious and in convulsions. These attacks recurred subsequently with great frequency and severity, sometimes as often as twenty times a day. A severe attack was characterized by a gradual onset of unconsciousness, marked pallor, suspension of respiration, disappearance of the pulse and heart sounds, and the assumption of a motionless state, which was soon followed by cyanosis and convulsions of variable duration and intensity. When the convulsion subsided, the face would become flushed, and there would be a gradual return to consciousness. Confusion of thought and disorientation usually followed such attacks. Mild attacks were characterized merely by confusion, dizziness, and more or less stupor or dulled sensitivity. Both adrenalin and quinidine aggravated the symptoms, and no other drug was of any avail. Intravenous injection of 50 c.c. of 50 per cent glucose solution was tried and gave considerable relief. The fatal attack occurred Dec. 30, 1936.

Electrocardiographic Observations.—Several electrocardiograms were made before the onset of the Adams-Stokes syndrome, and long tracings were obtained before, during, and after a prolonged seizure. Fig. 1A is a tracing obtained March 7, 1936. It shows partial 3:2 auriculoventricular block. The auricular rate is about 100 per minute and the ventricular rate 66. The auricular impulses are of normal sinus origin. The P-R interval of the effective impulses is 0.18 sec. The intraventricular conduction time is 0.12 sec. The QRS complexes are slurred and notched, and there is left axis deviation. The T-waves are markedly positive in Leads I and II and negative in Lead III. The curve shown in Fig. 1B was obtained May 26, 1936. It shows partial 2:1 auriculoventricular block, and occasionally a 3:2 relationship. The auricular rate is 62 to 66 and the ventricular rate, 31 to 44. The effective A-V conduction time, as well as the character of the ventricular complexes, is the same as on the previous occasion. The voltage, especially that of the T-wave, however, is definitely lower. In Lead III the T-wave is now diphasic.

Tracings were obtained at various times between paroxysms, and during short periods of drowsiness and transient loss of consciousness, prolonged unconsciousness and convulsions, immediately following the convulsions, and after the return to consciousness. Fig. 2 (A to U) shows selected portions of the electrocardiograms depicting the various phases.

Before a major paroxysm the auricular rate was 115 to 120 per minute, and the ventricular complexes appeared irregularly. Some of the ventricular complexes were of the supraventricular type with prolongation of intraventricular conduction time to 0.12 sec., as in Fig. 2, A and C. These are frequently interrupted or completely replaced by showers of ectopic ventricular impulses originating in various parts of the ventricles, as in Fig. 2, A, C, D, F, and I. These impulses frequently form short paroxysms of tachycardia, usually at a rate of about 220 per minute, as in Fig. 2, B and E. In nearly all of these short paroxysms some of the features of the QRS complexes are decipherable. The contiguous impulses in each group bore a close resemblance to each other but usually differed from those of another group. Occasionally a sudden change was noted in the appearance of the complexes in the same group. In

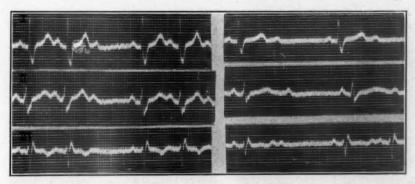


Fig. 1.—A, Three standard leads, March 7, 1936. Partial 3:2 auriculoventricular block, auricular rate 100, ventricular rate 66: effective auriculoventricular conduction time 0.18 sec.; intraventricular conduction time 0.12 sec.; slurred and notched QRS complexes.

B, Three standard leads, May 26, 1936. Partial 2:1 and occasional 3:2 auriculoventricular block; auricular rate 62 to 66, ventricular rate 31 to 44; voltage of all complexes lower.

such instances two or three complexes of similar appearance were succeeded by a complex of intermediary appearance, as seen in Fig. 2, E. The auricular rate was always slightly accelerated during and after such short paroxysms, but after a long paroxysm it was always slowed. After some paroxysms the auricular waves were inverted, as in Fig. 2, I.

The appearance of the ventricular complexes in any paroxysm depended upon the rate. Above 250 per minute the complexes assumed the appearance of undulations of various heights and shapes, and the QRS and T components were not decipherable, as in Fig. 2, G, J, K, L, M, N, and O. As slowing occurred, the QRS and T components became more or less evident again, as in Fig. 2, H, P, and Q.

Regardless of the appearances of the oscillations in each paroxysm, the duration of each cycle is almost an exact submultiple of the rate. Thus,

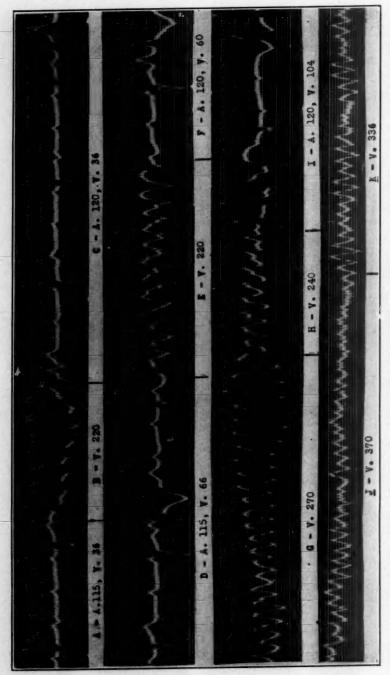


Fig. 2.—4, Regularly recurring auricular impulses: two supraventricular impulses with different spread. B, Ventricular tachyoradia, deformity of ventricular impulses; C, auricular and Ventricular impulses, supraventricular type, ending by ventricular
premature contraction; D, multicoal ventricular premature contractions; E, short paroxysm of ventricular tachycardia, marked deformity of impulses; F, acceleration of auricular rate following paroxysm; G, recurring ventricular oscillations, more rapid rate
with disappearance of the QRS markings; H, slowing of rate and reappearance of markings; I, inverted auricular impulses following
paroxysm; J, rapid ventricular oscillations; K, somewhat slower ventricular oscillations. A, auricular rate; V, ventricular rate.

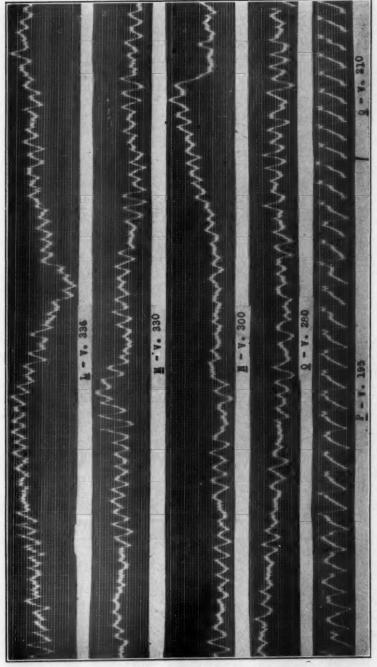


Fig. 2 Cont'd.—L, M, N, and O, Continuous oscillations with progressively slowed rate, marked deformity of the oscillations, no isoslectric level: p and Q, continuation of O with marked slowing of rate and reappelarance of recognizable ventricular complexes, although markedly deformed at first. Isoslectric level present and complexes are of almost equal voltage.

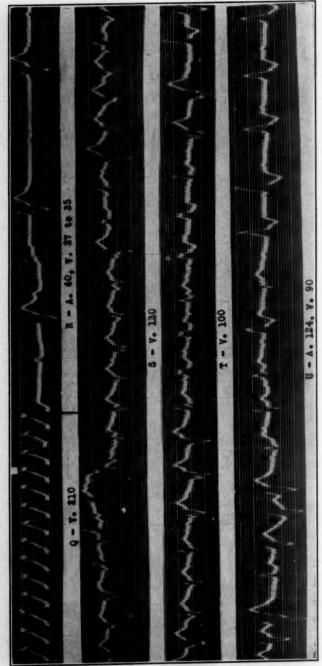


Fig. 2 Cont'd.—R, Postparoxysmal period, marked slowing of auricular and ventricular rate. S, T, and U, Multifocal id?oventricular impulses with progressive slowing of rate. A, auricular rate; V, ventricular rate.

in Fig. 2, G, when the rate is 270 per minute, the duration of each complete cycle is approximately 0.20 sec., whereas in Fig. 2, J, when the rate is 370 per minute, the average cycle measures about 0.16 sec.

The highest rate of oscillations in the entire series was about 370 per minute, shown in Fig. 2, J. In all long paroxysms the initial rate was always high, and, as the condition progressed, it gradually slowed, as in Fig. 2, J, K, L, M, N, and O, which comprises nearly an entire paroxysm. As the rate comes down to 195 per minute, as in Fig. 2, P, the QRS complexes are again clearly decipherable. The oscillations become more regular, and the voltage more uniform. This equality is more marked near the termination of the paroxysm, seen in Fig. 2, Q, even though the rate again increases slightly.

Superimposed on the main oscillations are numerous fine undulatory movements, caused undoubtedly by somatic muscular tremors.

The termination of a long paroxysm was always abrupt, as shown in Fig. 2, R. The auricular impulses reappear at a rate of 60 per minute, with moderate sinus arrhythmia. The ventricular impulses are of a supraventricular type with prolongation of the intraventricular conduction time to 0.12 sec. and with marked slurring and notching. The rate is 27 to 35 per minute, and the beating is somewhat irregular. This period lasted about five minutes and was followed by ectopic ventricular impulses originating in various foci (Fig. 2, S, T, and U) which entirely replace the usual impulses. The auricular rate is accelerated to 124 per minute and the ventricular rate to 130 in Fig. 2, S, coming down to 100 in T and to 90 in V. The auricular impulses are frequently buried.

SUMMARY

A case of recurring Adams-Stokes syndrome induced by transient ventricular fibrillation is reported. The attacks occurred at intervals of about seven weeks and recurred as often as twenty times a day. The longest individual attack lasted three and one-half minutes.

The prefibrillation phase was characterized by complete auriculoventricular dissociation with recurring multifocal ventricular impulses. The period of actual fibrillation presented a phase resembling paroxysmal tachycardia and a later, more advanced phase of irregular rapid undulatory movements. The highest oscillatory rate was 370 per minute; the rate was highest at the beginning of the paroxysm, and slowed gradually as it progressed. When the rate slowed to about 200 per minute, the electrocardiogram again assumed the appearance of ventricular paroxysmal tachycardia. The time interval of a complete oscillatory cycle was almost an exact submultiple of the rate of the group of oscillations in which that cycle belonged.

The immediate postfibrillation phase was characterized by abrupt cessation of fibrillation and very slow resumption of auricular and ventricular activity.

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PRIMARY TUMOR OF THE HEART PRODUCING AN UNUSUAL CARDIAC SHADOW IN THE ROENTGENOGRAM*†

REPORT OF A CASE

DUDLEY W. BENNETT, M.D., JEROME KONIGSBERG, M.D., AND WILLIAM DUBLIN, M.D. SAN FRANCISCO, CALIF.

CASES of tumor of the heart are reported from time to time, and in a few instances the diagnosis has been made before death. The presence of a tumor may be suspected when roentgenograms show that there is localized enlargement of the heart or irregularity in its contour. In the following case, although the diagnosis was not made, a tumor within the left auricle was found to be responsible for roentgenographic changes of this kind.

History.—The patient was a married Guatemalan woman, 37 years of age. On admission to the hospital she complained of cough, pain in the chest and lower abdomen, pains and aches in the extremities, and diarrhea. These symptoms had been present for only a few days. Little other information could be obtained regarding her present illness.

In childhood she had had malaria and smallpox. Her tonsils had been removed when she was 22 years old. Six years before admission, she had contracted gonorrhea, and pelvic inflammation had resulted; she married shortly afterward but never became pregnant. One year before admission salpingo-oöphorectomy and appendectomy were performed, and during her convalescence she developed what was diagnosed as bronchopneumonia. Six months later she began to complain for the first time of attacks of wheezing and difficulty in breathing. These symptoms were associated with weakness and dyspnea on moderate exertion. The attacks were thought to be asthmatic and were relieved to some extent by epinephrine.

Physical Examination.—The patient was a moderately obese, dark-complexioned woman who was orthopneic and perspiring profusely. She appeared to be weak, complained of a feeling of retrosternal "tightness," and had an expiratory wheeze. The integument, lymph nodes, head, and neck were normal. The chest was symmetrical in outline. The breasts were small. Respiratory movements were somewhat limited but were equal on both sides. Except for prolongation of the expiratory phase, auscultation of the lungs showed nothing abnormal. The area of cardiac dullness extended 11 cm. to the left of the midsternal line in the fifth intercostal space. All of the heart sounds were accentuated, especially the pulmonic second. The rate was 120, the beating regular. No adventitious sounds were audible. The peripheral vessels were normal. The blood pressure was $110/8\theta$. The abdomen showed an old lower midrectus scar and was moderately tender to palpation over both lower quadrants. There were no abnormal findings in the extremities or back and neurologic examination was negative. Vaginal examination revealed a tense, firm, very tender mass, with much surrounding induration, in the right fornix. Less induration was noted on the left side. Rectal palpation confirmed these findings.

^{*}From the Department of Medicine, University of California Medical School, the San Francisco Hospital, and the Department of Health, San Francisco.

Laboratory Examination.—A catheterized specimen of urine was normal except for the presence of a faint trace of albumin and a few granular casts. The blood Wassermann reaction was weakly positive (+), and the Kahn test strongly positive (++++). The hemoglobin was 12.4 gm. per 100 c.c. and the erythrocyte count 4,100,000 per cubic millimeter; the leucocyte count varied from 17,600 to 24,000 per cubic millimeter, and the differential leucocyte count showed that 91 to 93 per cent of the cells were polymorphonuclear leucocytes. The sedimentation time of the erythrocytes (Linzenmeier's method) was 18 mm. in 17 minutes. Blood cultures were negative on two occasions. The stool showed no abnormalities.

Subsequent Course.—During her stay in the hospital, the patient's temperature averaged 103° F., without much fluctuation. The pulse rate varied between 100 and 130 beats per minute, and the respirations between 20 and 36 per minute.

It was thought that the patient had a pelvic abscess and possibly an atypical pneumonia. Because of the latter possibility, a roentgenogram of the chest was taken, which was interpreted by Dr. A. J. Williams as follows: "The heart shadow

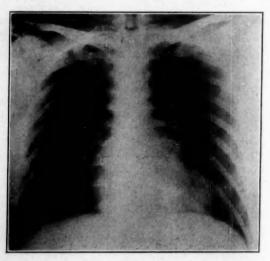


Fig. 1.—Posteroanterior roentgenogram, showing bulge in the upper left portion of the cardiac shadow due to tumor within the left auricle.

is enlarged both to the right and left. There is a large bulge in the region of the pulmonary conus. The aortic arch is not visible; it is either unusually small or has been displaced to the mid-line by the enlarged pulmonary conus. The lung fields are essentially clear. Mitral heart disease can be excluded by the absence of enlargement of the upper right border and of pulmonary vessel engorgement. The heart outline is that commonly produced by congenital anomalies such as an interatrial septal defect or a patent ductus arteriosus." (Fig. 1.)

The patient was prepared for drainage of the pelvic abscess. A few minutes after the induction of nitrous oxide and oxygen anesthesia, the heartbeat and respiration stopped. Administration of the anesthetic was discontinued, and stimulants were given, including epinephrine intracardially. The heartbeat and respiration were restored, and the blood pressure rose to 110/80, but the patient remained unconscious. Without further anesthesia, the abscess was opened by a posterior colpotomy, and drained of 200 to 300 c.c. of foul-smelling, purulent material which on culture yielded a variety of aerobic and anaerobic cocci and bacilli, but no B. coli.

The patient continued in a comatose state, and, except for spasmodic contractions of the muscles of the face and upper extremities, did not respond to further stimulation. She expired nine hours after being returned to the ward.

Post-Mortem Examination.* (excerpts).—"Each pleural cavity contained about 200 c.c. of slightly cloudy, bloodstained, amber fluid. There were a few adhesions but the pleural surfaces were thin and glistening. The lungs were soft, somewhat soggy, and crepitation was diminished. The cut surface was rather moist, slightly

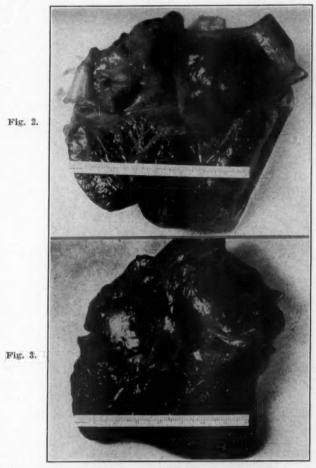


Fig. 2.—Tumor in the left auricle, intact. Fig. 3.—Tumor in the left auricle, after incision.

brownish, and displayed the usual pulmonary structure. The bronchioles were not thickened, and the bronchi contained small amounts of frothy fluid. Each lung weighed 345 gm.

"The pericardial sac had a clean, glistening lining and held a few cubic centimeters of bloodstained fluid. On the anterior surface of the heart there was a small mark left by the insertion of a needle for the administration of adrenalin. The heart itself was red-brown, moderately firm, and rather small in

^{*}Made by Dr. J. Carr and Dr. N. Rudo.

size. The epicardium contained a small amount of fat. The heart was opened in the usual manner, and the valves and chambers were examined. The wall of the right ventricle was slightly thickened, measuring about 0.5 cm. The tricuspid valve measured 10 cm. in diameter, and the pulmonary valve, 5 cm. In the left auricle

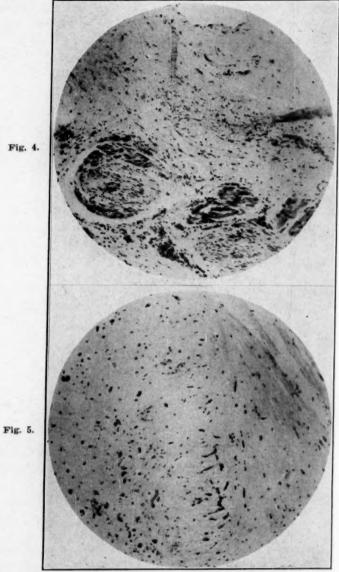


Fig. 4.—Photomicrograph of the base of the tumor, showing fragmented cardiac muscle tissue and tumor cells (×160).

Fig. 5.—Photomicrograph of the tumor (×100).

there was a large, irregularly rounded, glistening mass attached to the interauricular septum at the site of the fossa ovalis. The bulging of this mass through the fossa could be seen in the right auricle. The mass measured between 3.5 and 4 cm. in

diameter. Its color varied from yellow to red, and it had a slightly transparent appearance. It was somewhat rubbery in consistency and did not appear to be organized to any great extent. On the surface there were a few minute, rough gray flecks. As stated above, this ball-like mass was attached only to the medial wall of the left auricle; it filled the auricle almost completely. The lower part of the mass extended into the mitral orifice but did not seem to project far enough to interfere with the action of the valve. The mitral valve measured 8 cm. in diameter, and the aortic valve, 5 cm. The wall of the left ventricle was 1 cm. thick. No thrombus or abnormality was found elsewhere; the coronary orifices and vessels were open. The musculature showed grossly no evidence of fibrosis or infarction. The heart weighed 200 gm. (Figs. 2 and 3.)

"Microscopic Examination.—The auricular mass was composed of a relatively acellular, myxomatous, finely fibrillar material in which were thin-walled blood vessels and spindle-shaped connective tissue cells. The free surface was covered by a single layer of endothelium that was reflected from the wall of the auricle. At the base of the tumor there was a small amount of degenerate heart muscle with sparse lymphocytic infiltration (Figs. 4 and 5). There was no invasion of the interauricular septum, although it was somewhat compressed and the muscle was atrophic. The remainder of the heart muscle was not remarkable.

"Although a complete autopsy study was made, the only other important abnormality was generalized peritonitis; the abdominal cavity contained 1,000 c.c. of purulent fluid. An extensive pelvic abscess was present, but the pelvic structures were so distorted that it was impossible to determine its exact origin."

DISCUSSION AND CONCLUSIONS

It is seldom that a primary tumor of the heart is diagnosed during the life of the patient. The clinical manifestations depend upon the size and location of the tumor. A lack of any other adequate explanation for abnormalities in the size and shape of the heart or in the mechanism of the heartbeat, and for abnormal auscultatory signs, should suggest the possibility of a tumor of the heart.

In our case, the difficulty in interpreting the patient's rather indefinite history of respiratory and possible circulatory embarrassment was due partly to the presence, in addition, of a severe pelvic and abdominal infection that drew attention from the intrinsic cardiac disturbance. No adequate clinical study of her circulatory system was made. However, the unusual outline of the cardiac shadow seen in the roentgenogram of the chest indicated the presence of an abnormality of the circulatory system. This shadow was thought to be due to an abnormality of the pulmonary conus or artery, although no clinical signs of disease of these structures were present. The roentgenogram of her chest was obtained in order to investigate the possibility of pulmonary infection, rather than because of any positive evidence of circulatory disease as indicated by the physical examination.

It is believed that this patient died because of the presence of overwhelming infection but that the tumor in the left auricle, by interfering with the normal function of this chamber, was definitely a contributing factor.

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Department of Reviews and Abstracts

Selected Abstracts

Graybiel, Ashton and White, Paul D.: Diseases of the Heart: A Review of Significant Contributions Made During 1937. Arch. Int. Med. 61: 808, 1938.

This annual review includes all the literature of the past year with editorial evaluations. It is in the usual form. Notice has been given that if there is sufficient demand, reprints of each year's reviews will be prepared for distribution.

McCulloch.

Wolf, J., Mohr, M., and Kröger, E.: The Blood Supply of the Kidney After Ligation of Its Main Artery Supply. Ztschr. f. d. ges. exper. Med. 100: 485, 1937.

Ligation of the renal artery of one kidney causes hypertension and an increase in blood tyramine. It was found that the outflow of the renal vein from such a kidney is still one-tenth to one-fourth that from the other kidney. The blood comes in from the collaterals through the kidney capsule.

KATZ

Stoll, A.: New Developments in the Chemistry of Cardiac Glucosides. Ztschr. f. Kreislaufforsch. 30: 221, 1938.

The close relation of glucosides to bile acids and sterols has recently been shown and the structural formulas for the various genins like strophanthidin, digitoxigenin, gitoxigenin, dixogenin, and scillaridin A have been established. New glucosides have been found in certain plants and from these previously known glucosides have been split off as a result of enzymatic action. Work of this sort which the author details has permitted the isolation of pure glucosides and thereby allowed better standardization of these digitalis derivatives for clinical use.

KATZ.

Schneider, D.: Clinical Observations of the Action of Veritol. Klin. Wchnschr. 16: 736, 1937.

The preparation, veritol, is an oxyphenylmethylaminopropan. In 120 patients with collapse it caused a definite rise in blood pressure of longer duration than other drugs tried. Its action on intramuscular and intravenous use is rapid in onset. It has no effect on respiration and only a slight accelerating effect on the pulse. The blood sugar level is unaffected. Its action, as Rein has shown, is to empty the blood content of the blood reservoirs, to increase the venous tone, and to increase the minute volume blood flow.

KAT

Tislowitz, R., and Pines, I.: The Vagotonic Action of Vitamine B, on the Normal Dog's Heart. Klin. Wchnschr. 16: 923, 1937.

One to 2 mg. of pure vitamin B, daily causes sinus bradycardia and arrhythmia. This also occurs in acute experiments, one to two hours after 10-20 mg. of the vitamin. The possibility of using this vitamin in paroxysmal tachycardia is suggested.

Kama

Brandenburger, P.: Another Cause for Adams-Stokes Attacks. Ztschr. f. Kreislaufforsch. 30: 246, 1938.

Three cases are presented in detail in which cardiac standstill with dizziness and fainting followed sudden changes in the position of the head. In these patients an enlarged parotid gland was found which pressed on the carotid sinus, and the phenomena are attributed to this stimulation of the carotid sinus.

KATZ.

Sturm, A., and Dauter, H.: The Depressor Action of Choline Derivatives and Histamine (Observed in Man). Arch. f. exper. Path. u. Pharmakol. 185: 368, 1937.

Acetylcholine can cause blood pressure falls lasting for as long as two hours due apparently to cardiac action only. Doryl has a similar effect on blood pressure apparently due to vascular action. Histamine causes capillary enlargement and arterial and arteriolar dilatation, but this by causing increased venous return may lead to an initial blood pressure rise before the blood pressure fall appears.

KATZ.

Hoen, E., and Neuthard, A.: Pharmacologic Studies on the Minute Volume Output of the Normal Human Heart. Arch. f. exper. Path. u. Pharmakol. 185: 293, 1937.

Grollman's acetylene method for measurements was used. Caffeine, theobromine, and theophylline all increase minute cardiac output in ten to fifteen minutes, the increase being about 200 per cent for caffeine, 150 per cent for theophylline, and 100 per cent for theobromine. The action of caffeine lasts longest. The action of theobromine is irregular. Cardiazol (metrazol) increased minute volume output only 50 per cent; coramine, 125 per cent.

KATZ.

Schöne, G.: The Magnitude of the Circulation in Paroxysmal Tachycardia. Klin. Wehnsehr. 16: 804, 1937.

The method of Broemser and Ranke for determining minute volume of the circulation was used on two patients. In one with 1:1 auricular flutter (rate 297) the minute volume output during the attack was 1.89 liters, compared with a rate of 4.02 liters when the heart rate was normal. In the second case with a nodal tachycardia and rate of 154, the minute volume output decreased from 3.16 liters before the attack to 2.74 liters during the attack. In the first patient there was x-ray evidence of cardiac enlargement attributed to the excessive tachycardia.

KATZ.

Von Pein, H.: The Measurement of Gaseous Metabolism as a Test of Heart Function. Ztschr. f. klin. Med. 132: 227, 1937.

Oxygen consumption during stair climbing was measured, the expired air being collected in a Douglass bag. The oxygen debt and exercise excess oxygen consumption were increased in heart failure. In normal subjects the excess oxygen consumption is dependent on the amount of work, and the oxygen debt, on the rate of work. This test, the author found, permitted the early recognition of heart failure.

KATZ.

Von Gruber, Z.: The Electrocardiogram With Short P-R and Broadened QRS Complex. Ztschr. f. Kreislaufforsch. 30: 100, 1938.

This is a report of six cases. The author offers as an explanation the idea that under the influence of the sinus impulse, an extrasystole in the right auricle near the A-V junction is set up, with fixed coupling. The P-wave of this extrasystolic beat fuses with the QRS complex resulting from the spread of the sinus impulse to the ventricle and makes it appear long and the P-R short.

KATZ.

Huttmann, A.: The Auricular Electrocardiogram in Cor Bovinum. Ztschr. f. Kreislaufforsch. 30: 171, 1938.

Eight cases of cor bovinum are reported in which the P-wave was abnormally tall, broad and notched, and sometimes inverted in Leads II and III and sometimes splintered in Lead I. This is attributed to auricular hypertrophy.

KATZ.

Pröhlich, R.: The Electrical Axis of the Heart. Ztschr. f. Kreislaufforsch. 30: 251, 1938.

This is a mathematical and theoretical discussion to show that the "electrical axis" and the magnitude of the "manifest potential" are not in general related to the magnitude of the potentials developed in the heart. They are of value, however, in measuring the peripheral electrical field.

KATZ.

Kienle, F.: Chest Leads With Different and Indifferent Electrodes. Arch. f. Kreislaufforsch. 2: 224, 1938.

This is a 42-page presentation dealing with chest leads. The author used as his indifferent electrode a lead from copper wire mesh of a large electrode upon which the patient was placed. This electrode was grounded. Characteristic changes over the left ventricle were found in diseases of this chamber, and over the right ventricle when this was diseased. These consisted of inversion of T and depression of S-T (new technique).

KATZ.

Braun Menendez, E., and Moia, B.: Rapid Nodal Rhythm Alternating With Sinus Rhythm in Congestive Heart Failure. Rev. argent. de cardiol. 4: 329, 1937.

Rapid nodal rhythm alternating with sinus rhythm and auricular extrasystoles appearing in the same record taken in a man aged 45 years with congestive heart failure is described.

The strong jugular pulsations and ingurgitation, together with a palpable hepatic pulse, suggested a tricuspidal insufficiency. The graphic records showed, however, that the jugular wave and hepatic pulse were really due to the auricular contraction, unable to discharge its contents in the ventricle because of the simultaneous contractions. The phonocardiogram also showed a marked intensification of the first heart sound due to a true summation of auricular and ventricular sounds.

During the sinus rhythm both the venous pulse and heart sound records appeared normal again, and the hepatic pulse almost entirely vanished.

An esophageal lead allowed a correct visualization of the retrograde auricular wave in the electrocardiogram.

Upon moderate digitalization the nodal rhythm disappeared.

AUTHOR.

Chen-Lang Tung and Yin-Chang Ch'u, Shao-Hsun Wang, and Wan-Sen Ma: The Heart in Severe Anemia. Chinese M. J. 52: 479, 1937.

Ten patients suffering from severe anemia (hemoglobin about 2.5 gm. or 17 per cent), without any other discoverable factor that might cause heart disease, were observed for the effects of such anemia on the cardiovascular system, with clinical, radiologic, and electrocardiographic studies. In addition, venous pressure by the direct method and the arm-to-tongue circulation time were determined in most of the cases.

Three patients showed marked cardiac enlargement with little or no evidence of congestive failure. Six showed marked cardiac enlargement and marked congestive failure. One had a normal heart. Cardiac enlargement rapidly disappeared with rest and increase of the hemoglobin towards normal, and the heart assumed normal size and shape when the blood became normal. Diastolic cardiac murmurs encountered in two patients during the height of anemia disappeared with the latter. All patients except one had sinus tachycardia and large pulse pressure.

Six patients presented physical evidence of marked congestive heart failure, including the elevation of venous pressure. The relative duration of electrical systole was prolonged. In spite of elevated venous pressure the circulation time remained normal.

It is concluded that marked cardiac enlargement and marked congestive heart failure may result from prolonged, severe anemia alone, particularly in individuals who have extra demands on their circulatory system (physical exertion, fever, pregnancy, parturition, etc.). Both cardiac enlargement and cardiac failure in such cases disappear rapidly, when the anemia is removed. "Anemia heart" should be considered a clinical entity.

AUTHORS.

Kisch, F.: Sudden Cardiac Death in Angina Pectoris in the Absence of Coronary Thrombosis. Klin. Wchnschr. 16: 708, 1937.

In 13 cases out of 36 of sudden death with angina pectoris, no coronary thrombosis was found. In all of these either syphilitic closure of the mouths of the coronaries or coronary occlusion of the arteries by arteriosclerosis was found. The author considers death as reflex in origin.

KATZ.

Starr, Isaac, Gamble, C. J., Donal, J. S., and Collins, L. H.: Estimations of the Work of the Heart During and Between Attacks of Angina Pectoris. J. Clin. Investigation 17: 287, 1938.

In four cases of cardiac pain, three of them suffering from typical angina pectoris, estimations of cardiac output, basal metabolic rate, blood pressure, pulse rate, and respiration were made during the pain and, under comparable conditions, when the patients were free from it. In one case a necropsy was secured. The changes following relief by nitroglycerin were studied in two cases.

The results indicate that the work of the heart was significantly greater during the pain than when the patients were free from it.

The results are consistent with the widely accepted view that cardiac pain is caused by situations demanding increased cardiac work when the heart's blood supply cannot be increased correspondingly.

AUTHOR.

Graef, Irving, Berger, Adolph R., Bunim, Joseph J., and de la Chapelle, Clarence E.: Auricular Thrombosis in Rheumatic Heart Disease. Arch. Path. 24: 344, 1937.

Certain conditions appear to favor the development of auricular thrombi. These are severe mitral stenosis, together with congestive heart failure, auricular fibrillation, and continued local inflammation. On analysis of these factors, the persistence of active inflammation appears to be the chief one in the light of present knowledge.

The occurrence of fibrin-staining material beneath the endocardium can be differentiated from the focal swelling of collagen in the same structure by the use of Mallory's phosphotungstic acid-hematoxylin stain. The fibrin-staining material thus demonstrated is presumably derived from the proximate blood stream.

AUTHOR.

Schneyer, K.: Pulsus Rarus in Aortic Stenosis. Ztschr. f. Kreislaufforsch. 30: 161,

Sixteen cases of aortic stenosis were found in 2,851 cases of valvular disease. The heart rate in these cases of aortic stenosis was between 58 and 62 beats per minute. Isthmus stenosis of the aorta has faster rates. The author does not believe this slow rate to be reflex in origin.

KATZ.

Sutton, Lucy Porter, and Dodge, Katharine G.: The Relationship of Sydenham's Chorea to Other Rheumatic Manifestations. Am. J. M. Sc. 195: 656, 1938.

Sydenham's chorea is not usually per se a serious condition.

Rheumatic heart disease develops in approximately 20 per cent of patients who have had chorea as the only clinical manifestation of rheumatic infection.

The child who begins his rheumatic disease with chorea runs a 50 per cent chance of developing heart disease.

The child who begins with chorea runs a 50 per cent chance of developing other rheumatic manifestations later, of if muscle and joint pains are included, a 75 per cent chance. Emotional factors are no more important, and probably less so, in initiating an attack of chorea than preceding acute infection, including rheumatic polyarthritis.

Chorea should continue to be regarded not only as a manifestation, but as a major manifestation of rheumatic infection.

AUTHOR.

Southworth, Hamilton, and Stevenson, Charles Summers: Congenital Defects of the Pericardium. Arch. Int. Med. 61: 223, 1938.

A description is given of a patient showing congenital absence of the left leaf of the parietal pericardium, with an interpleural window in the upper portion of the anterior mediastinum.

This is the first case reported in the literature in which adequate clinical date have been given and in which fluoroscopic examination has been included.

In a survey of the literature forty-five definite instances of this defect have been found, together with seven other instances in monstrous births and two doubtful cases.

Analysis of these cases reveals that the defect was almost invariably on the left; that in 76 per cent of the cases it was so completely on that side that the heart and the left lung were in a common serous cavity; that in 77 per cent of the cases the subject was a male; and that the condition is not incompatible with normal life, having in only one instance been directly responsible for death and having otherwise possibly caused cardiac symptoms in only three cases.

Unexplained cardiac enlargement may occur (in about half the cases), but it is apparently not related to the presence or absence of adhesions.

The chief danger from the defect lies in exposing the heart to pulmonary infection, with death in 27 per cent of the cases, including our own, associated with pleuropericarditis.

Although in no case as yet has the condition been diagnosed ante mortem, this should be possible in some instances on the basis of certain criteria adapted from Maude Abbott.

AUTHOR.

Welper, W.: Hyperergic Thromboendarteritis in the Lungs of Infants in the Presence of Eclampsia of the Mother. Arch. f. Kreislaufforsch. 2: 210, 1938.

In a 3-day-old infant evidence was found of thromboendarteritis in the peripheral arteries of the lung. The changes resemble those seen in allergic disorders and are attributed to the severe eclampsia of the mother, suggesting that eclampsia is allergic in character (?).

KATZ

Waring, J. I.: Nutritional Heart Disease in Children. Am. J. Dis. Child. 55: 750, 1938.

Nutritional heart disease is not uncommon among negro children in Charleston, S. C. Thirteen cases summarized here suggest that the cardiac changes are due not entirely to a lack of vitamin B but to a rather more general deficiency of dietary materials and that a satisfactory response to dietetic treatment may be expected in cases in which the illness is not too far advanced.

AUTHOR.

Bland, Edward F., and Jones, T. Duckett: Fatal Rheumatic Fever. Arch. Int. Med. 61: 161, 1938.

Since 1921 (sixteen years) approximately 1,500 children and adolescents under the age of 21 years have received hospital care at the House of the Good Samaritan for rheumatic fever and chorea. The subsequent course and present status of this large group are known. We have presented in this report data relevant to the 306 patients who have died. Post-mortem examination was made in 74 instances (24 per cent). From a consideration of this group of patients who have died the following conclusions may be cited:

- 1. Rheumatic fever has been the outstanding cause of death and was directly responsible for the fatal issue in 250 instances (82 per cent).
- 2. The early years after the onset of the disease have proved to be a critical period. In approximately half (47 per cent) of the fatal cases death occurred during the first three years and in two-thirds (62 per cent) during the initial five years.

- 3. Thereafter the extent of residual cardiac enlargement (dilatation) and, to a lesser degree, the rapidity with which it developed have served as the most reliable criteria of the severity of the preceding infection as well as an index of the future susceptibility of the individual patient to subsequent fatal rheumatic fever.
- 4. The age of the patient at the time of onset of rheumatic fever (or chorea) during the first fifteen years of life has been of no significance so far as subsequent longevity is concerned.
- 5. The manifestations of fatal rheumatic fever had been stressed and contrasted with the generally accepted clinical picture of the disease.

AUTHOR.

Bruger, Maurice, and Fitz, Fred: Experimental Atherosclerosis: 1. Effect of Prolonged Administration of the Thyrotropic Factor. Arch. Path. 25: 637, 1938.

The feeding of iodine prevents the deposition of cholesterol in the arteries of rabbits fed cholesterol. Thyroidectomy abolishes this protective action of iodine. This striking relationship between experimental atherosclerosis and the function of the thyroid gland led the writers to learn whether the thyrotropic factor, from the pituitary gland, has an effect on experimental atherosclerosis in rabbits (cholesterol-feeding method). The results were as follows: The aortas of cholesterol-fed rabbits contained several times as much cholesterol as normal controls. The aortas of rabbits receiving injections of thyrotropic factor contained about the same amount of cholesterol as normal controls. The aortas of rabbits being fed cholesterol and receiving injections of thyrotropic factor contained, on the average, nearly twice as much cholesterol as the cholesterol-fed rabbits not receiving thyrotropic factor. In an attempt to explain these findings some theoretical considerations are discussed.

MONTGOMERY.

Immel, R.: Hemostatic Pressure Rise and the Arterial System. Klin. Wchnschr. 16: 956, 1937.

When a patient stands up, the pressure in the brachial artery increases as a result, so the author states, of an increase in tone of the medium-sized arteries.

KATZ.

Jones, E. Idris: A New Syndrome Apparently Due to Over-Activity of the Posterior Pituitary. Lancet 1: 11, 1938.

A patient in whom hypertension, hyperchromic anemia, achlorhydria and abnormal carbohydrate tolerance were present has been observed over a period of eight months. The fact that in animals it is possible to produce hyperchromic anemia and achlorhydria by injection of posterior pituitary extract suggested that the combination of hyperchromic anemia and hypertension was not fortuitous but that the syndrome might be due to overactivity of the posterior pituitary. An extract with pressor and antidiuretic activity was obtained from the urine of this patient. This was considered additional evidence of hyperfunction of the posterior pituitary. Treatment with liver extract resulted in a return of the blood count and hemoglobin to normal, a more normal carbohydrate tolerance curve, and a fall in the blood pressure to normal levels. It is suggested that this is a new syndrome due to hyperfunction of the posterior pituitary.

HINES.

Bergfeld, W., and Meessen, H.: Hypophysis and Hypertension. Ztschr. f. klin. Med. 132: 283, 1937.

In 8 out of 9 cases of malignant nephrosclerosis with hypertension, examination showed basephylic cellular increase in the hyperhysis. This was true also in 8 out of 9 cases of hypertension with chronic nephritis. It was absent in 4 cases of acute and subacute nephritis. It was found in only 2 out of 50 controls.

KATZ.

Turner, Roy H.: Studies in the Physiology of Blood Vessels in Man: Apparatus and Methods: I. A Sensitive Plethysmosphygmograph for a Portion of the Finger. J. Clin. Investigation 16: 777, 1937.

An apparatus designed particularly for measuring volume changes due to the state of fullness of the blood vessels of a sharply defined portion of the human finger is described as to construction, mode of operation, and working characteristics. The apparatus makes a graphic record of pulse volumes as small as 0.1 c.mm. and of gradual volume changes as great as 1,000 c.mm. The pulse recorder, which employs an optical capsule in which stretching of the rubber membrane is largely avoided, shows high sensitivity, low moving mass, responds well to volume changes at a frequency up to 40 cycles per second and with diminished amplitude to 60 cycles per second, and is well damped. The apparatus and method interfere to a minimum with the body part under study except through undesirable temperature and humidity of the air in contact with the skin.

AUTHOR.

Sodeman, W. A.: Studies in the Physiology of Blood Vessels in Man: Apparatus and Methods: II. A Method for the Determination of the Volume of the Soft Tissue About the Terminal Phalanx of the Human Pinger. J. Clin. Investigation 16: 787, 1937.

This communication deals with the method for estimating in the living human being the volume of soft tissue in that portion of the finger which, for lack of a better term, is called the finger tip.

The method consists of a determination of the total volume of the finger tip, an estimation of the bone volume, and a calculation of the soft tissue volume by difference. The finger tip has been defined in terms of skin markings as that portion of the finger distal to a plane passing through the center of the dorsal and palmer skin crease at the distal interphalangeal joint. This plane passes through the distal end of the second phalanx.

McCulloch.

Turner, Roy H., Burch, George E., and Sodeman, William A.: Studies in the Physiology of Blood Vessels in Man: III. Some Effects of Raising and Lowering the Arm Upon the Pulse Volume and Blood Volume of the Human Pinger Tip in Health and in Certain Diseases of the Blood Vessels. J. Clin. Investigation 16: 789, 1937.

Changes in total blood volume and pulse volume of the finger tip due to elevation and depression 45 cm. from heart level for a group of males including normal subjects and patients suffering from various vascular abnormalities are reported and discussed.

Pulse volume increased with elevation and decreased with depression of the finger tip, and total volume changed in the opposite direction. The adaptive mechanisms are discussed in terms of behavior of various vessel groups. The influence of position upon pulse volume is ascribed to change in distensibility of both arterial and venous vessels and to changes in frictional resistance to blood flow and consequent changes in smoothing effect on the pulse wave which are predominantly arterial.

AUTHORS

Rubenstone, Abraham I.: Postoperative Circulatory Collapse Accompanied by Acidosis. Pennsylvania M. J. 41: 673, 1938.

Vascular changes rather than the heart are involved in postoperative circulatory collapse. Chemical imbalances may further aggravate the patient's condition. Four cases are presented. In all four the alkali reserve was between 25 and 36. Three of the patients recovered, and in them the alkali reserve returned to normal or nearly to normal. Treatment advised consists of blood transfusions, oxygen tent, water, chloride, or Ringer's solution and strychnine, pitressin, ephedrine, and adrenalin. In acidosis buffer solutions, such as Hartmann's, are indicated. Digitalis is of secondary importance.

MONTGOMERY.

Budelmann, G.: Cardiac Pulmonary Congestion in Practice. Deutsche med. Wehnsehr. 63: 1105, 1937.

Congestion in the lung occurs when the left heart does not pump out the blood pumped into the lungs by the right heart. This interferes mechanically with the expansion of the lungs, decreases vital capacity, and so explains the sense of chest oppression in many of these patients. It may cause dyspnea with or without evidence of interference of gaseous exchange in the lungs. The x-ray demonstrates only extreme forms of congestion although the end results of milder chronic forms may appear as induration and bronchial involvement. In treatment, two principles are important: viz., improve the power of the left heart and decrease the venous return to the right heart.

KATZ.

Gibson, John G., and Evans, William A., Jr.: Clinical Studies of the Blood Volume. III. Changes in Blood Volume, Venous Pressure, and Blood Velocity Rate in Chronic Congestive Heart Failure. J. Clin. Investigation 16: 851, 1937.

In heart disease the change from the compensated to the decompensated state is accompanied by a progressive increase in the volume of plasma and red cells.

This increase is shared to a slightly less extent by the plasma than by the corpuscles, resulting in a slight concentration of the blood.

The average degree of increase in blood volume above normal parallels the average degree of elevation of venous pressure and slowing of circulation time.

During recovery from congestive failure there is a diminution in both plasma and cell volume, the degree of decrease in plasma in most cases being at first more rapid than that of the corpuscles, resulting in varying degrees of blood concentration. With continued compensation the proportion of cells to plasma returns to within normal limits. The decrease in total volume parallels the degree of clinical improvement.

In no case was an increase in volume during recovery from chronic congestive failure observed. Relapses to more severe degrees of circulatory failure are accompanied by maintained elevation of, or further increases in, blood volume.

AUTHORS.

Thomson, William A. R.: The Organic Mercurial Diuretics in the Treatment of Cardiac Oedema. Quart. J. Med. 6: 321, 1937.

The therapeutic value of the various organic mercurial diuretics, known by the trade names of salyrgan, neptal, novurit, mersalyl, and novurit suppositories, has been investigated in 66 patients, 61 of whom had congestive heart failure with edema. Of these, 33 had auricular fibrillation, and 28 had normal rhythm.

The average twenty-four-hour excretion of urine per intravenous injection of 2 c.c. was for salyrgan 2,670 c.c. (94 oz.), for neptal 2,670 c.c. (94 oz.), for mersalyl 2,860 c.c. (101 oz.), and for novurit 3,000 c.c. (105 oz.).

The intramuscular route was seldom employed, but of 18 injections of neptal, 9 were intramuscular and 9 were intravenous. The average twenty-four-hour diuresis per injection was 2,670 c.c. (94 oz.) for the intravenous group and 2,190 c.c. (77 oz.) for the intramuscular group.

Mercurial (novurit) suppositories were successfully employed on 208 occasions with an average diuresis per suppository of 2,360 c.c. (83 oz.).

Almost without exception the administration of ammonium chloride, 60-90 grains (4-6 gm.) daily, for the two or three days preceding and on the day of the administration of the mercurial diuretic, resulted in an increased diuresis.

The administration of digitalis had no appreciable effect upon the diuretic response to the mercurial diuretics. Even when patients with auricular fibrillation were separately considered, the diuretic response was little affected by digitalis.

No serious toxic effects were observed during this investigation.

The organic mercurial diuretics are safe and efficient and have an almost universal application in the treatment of cardiac edema. There is little to choose between the various preparations now available, except that those containing the ophyllin are rather more active.

The dose, either intravenous or intramuscular, is 2 c.c. of the solution as supplied by the manufacturers. The intravenous route is preferable. Two clear days should elapse between the injections (or the suppositories). Preliminary small doses are not required. If local conditions preclude the use of an undiluted injection, it is better to make use of the suppositories.

Mercurial (novurit) suppositories are satisfactory and easily administered, though the resulting diuresis is less than from an injection. They should, when possible, be preceded by an aperient two nights before or by an enema a few hours before.

The optimum dosage of ammonium chloride is 20-30 grains (1.3-2 gm.) thrice daily, i.e., 60-90 grains (4-6 gm.) daily, for two or three days preceding, and on the day of, the administration of the mercurial diuretic. For practical purposes this means continuous administration when the mercurial preparation is being given regularly on every third day (i.e., with two-day intervals).

Mercurial diuretics appear to act as efficiently in dispersing edema whether digitalis is being given or not, although digitalis is generally indicated and should be given because of the failure. Indeed, the mercurial diuretics should take precedence even over digitalis where edema is the prominent feature in congestive failure. Hydrothorax or ascites, as well as anasarca, will respond to these preparations, which should make the use of paracentesis, skin puncture, or Southey's tubes a rare necessity. Where there is cardiac asthma, orthopnea, and enlargement of the liver—yet without external edema—they should be used; and for incipient heart failure they find a place with digitalis in preventing the onset or recurrence of edema.

AUTHOR.